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NZAS Awards 2017

Report on the Marsden Fund

Zealandia or Pacifica?

Antarctic research

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A forum for the exchange of views on science and science policy

Editor: Allen Petrey
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Contents

Cover: Recipients of NZAS Awards for 2017 (see pages 73–74): From left to right at back, Carolyn Burns, Colin Green, Alistair Gunn, Joanne Davidson, Justin Dean, Laura Bennet, Christian Hartinger, with NZAS President Craig Stevens; in front Hine Hou Alexandra Mercier (on behalf of Ocean Mercier)

Photo by Carl Anderson

Instructions to Authors

New Zealand Science Review provides a forum for the discussion of science policy. It also covers science education, science planning, and freedom of information. It is aimed at scientists, decision makers, and the interested public. Readability and absence of jargon are essential.

Manuscripts on the above topics are welcome, and should be emailed to the editor (editor@scientists.org.nz).

As well as full papers, short contributions, reports on new developments and conferences, and reviews of books, all in the general areas of interest detailed above, are invited. The journal may also accept reviews of a general nature and research reports.

Full manuscripts (with author's name removed) will be sent for peer review, and authors will be sent copies of the reviewer's comments and a decision on publication. Manuscripts should not normally have appeared in print elsewhere, but already published results discussed in the different, special context of the journal will be considered.

Manuscripts should be accompanied by biographies of not more than 100 words on each author's personal history and current interests. Authors are also expected to supply a suitable high-definition passport-size photograph of themselves. This will be published with the article.

Articles may be submitted in MS Office Word, rich text format, or plain text. Diagrams and photographs should be on separate files (preferably eps, tif, jpg, at 300 dpi), not embedded in the text.

All tables and illustrations should be numbered separately – Tables 1, 2, 3, 4, etc., and Figures 1, 2, 3, 4, etc. – and be referred to in the text. Footnotes should be eliminated as far as possible. Diagrams and photographs will be printed in black and white, so symbols should be readily distinguishable without colour, and hatching should be used rather than block shading. However, colour may be used if the author or the author's institute is willing to pay for the added cost.

References should preferably be cited by the author–date (Harvard) system as described in the Lincoln University Press *Write Edit Print: Style Manual for Aotearoa New Zealand* (1997), which is also used as the standard for other editorial conventions. This system entails citing each author's surname and the year of publication in the text and an alphabetical listing of all authors cited at the end. Alternative systems may be acceptable provided that they are used accurately and consistently.

In this issue

In his article, *A review of the new MBIE Report on the Marsden Fund,* Geoff Chambers says that MBIE has done the scientific community a great service in putting this report together and has touched on most, if not all, of the difficulties that applicants have found when trying to secure research support from this source. However, it is also Geoff's view that MBIE is wide of the mark in their analysis and thus cannot be said to fully appreciate the frustrations of those they serve. Geoff lays out what he takes to be the key issues with the fund and offers some comments on addressing these issues, which he hopes will excite a debate around this most important resource for New Zealand researchers.

Recent reinterpretation of the geology of New Zealand indicates that it is part of a much larger and submerged continent – Zealandia – Mortimer & Campbell (2014: 116)* and dismisses an earlier proposed continent – Pacifica.

In *The Zealandia continent: a worthy replacement of Pacifica?* Peter Hodder traces, through citation analysis, the development and demise of the idea of 'Pacifica'. Based on this analysis, he suggests that 'Zealandia' is historically inaccurate and politically contentious. A politically acceptable name for the continent that does not kindle post-colonial dissent might be 'Vallardia', reflecting the sixteenth century Portuguese maps of the region.

He accepts, however, that 'Vallardia' is unlikely to find favour in this day and age. Revival of the name 'Pacifica' is offered as a solution to this conundrum

New Zealand's Antarctic science is organised into 'Events', each given a 'K' (for Kiwi) designation. The formative work for one of the better known and longer-lived Events, K131, took place in the 1980s. Timothy Haskell, then a scientist at the Physics and Engineering Laboratory, DSIR, along with Bill Robinson and Arnold Heine, developed methods to gauge the Erebus Glacier tongue's inner mechanical workings and how, and why, the tip would periodically calve.

In *K131 Antarctic sea ice science: A case study of infrastructure, strategies, and skills,* Craig Stevens, Natalie Robinson and Pat Langhorne trace the evolution of the team and infrastructure that evolved from this early Antarctic ice–ocean work.

*Mortimer, N.; Campbell, H. 2014. *Zealandia: Our Continent Revealed*. London, UK: Penguin.

As the authors rightly claim, over the past 30 years, K131 science has not only developed an understanding of the physical processes of how the components of an ice-covered ocean work, but also evolved robust operational methods for experimentation on ice–ocean interaction. The approach has brought together physicists of many flavours, engineers, mathematicians, oceanographers, biologists, biogeochemists, modellers and artists. It is a demonstration of how to do big science in serial-meandering mode.

In the short article, *Sleeping with the enemy: Science and the humanities still pass each other like ships in the night* re-published from The Asia Pacific Policy Society, Roger Bradbury muses on the help policy advisors might take from the latest science insights in complexity, tipping points and transfer entropy. If you care to share Roger's article with a policy advisor you might be given a copy of the new book by Terry Bossomaier and co-authors, *Introduction to Transfer Entropy*.

Our book review is of Richard Dawkins' *Science in the Soul: Selected Writings of a Passionate Rationalist* reviewed by Geoff Gregory, and the news items carried in this issue identify the 2018 Rhodes Scholars-elect and summarise the report released in December 2017 on Stage 2 of the Inquiry into Havelock North Drinking Water.

Finally in this issue we celebrate the 2017 NZAS Awards and note that Dr Ocean Mercier, of Victoria University of Wellington, is the winner of the 2017 Cranwell Medal. The Cranwell Medal, formerly the Science Communicator Medal, honours New Zealand botanist Lucy Cranwell (1907– 2000), who during a long career spanning much of the 20th century developed a reputation as an engaging science communicator.

Allen Petrey
Editor

President's Report 2016/17*

It as been a big year for science, and so the Association has been kept busy. National and international politics have all had science elements to their discourse. With the evolving local science media, the New Zealand Association of Scientists still maintains a good profile when any science issue comes up. I believe this is as strong an indication of the health of the Association as membership numbers.

Our key event is the annual conference, and this year it had a theme around science outside the big institutes and usual players. If we want science and the Association to continue to be part of the science story in our society we have to get more people valuing, understanding and feeling part of science. Our secret weapon this year was youth – we invited along a group of high school science students and they really stamped a positive mood on the day.

The March for Science was an event that gained international attention and the NZAS had a high profile in the proceedings and discourse around what the day involved.

We start the New Year with a new government and a new Minister for Research, Science and Innovation, Dr Megan Woods, whom we have engaged with prior to the election. She attended the pre-election discussion on science hosted jointly by ourselves and the Public Service Association. We look forward to contributing further to debates around science. As noted previously, one of the things I will seek to promote is some form of Science Meets Parliament equivalent.

The Association was proud to support a public talk on Suffrage Day (18 September) exploring how we can reach equity for all scientists. I had the pleasure of introducing Dr Zuleyka Zevallos, an applied sociologist and an Adjunct Research Fellow with Swinburne University. She developed and managed Science in Australia Gender Equity (SAGE), an initiative of the Australian Academy of Science. Panellists Joanna Kidman, Izzy O'Neil, Di Tracey, and Richard Blaikie gave a local perspective on the ideas, and NZAS past-President Nicola Gaston closed the evening.

We maintained a high media profile, with press releases on a number of scientific issues including the science march. We also contributed to discussions on the future of the Marsden Funds, the MBIE definition of Impact, and the Royal Society report on Health and Climate.

It was a pleasure to see the reception of the renaming of the Research Award as the Beatrice Hill Tinsley Award. The coming awards will see us rename the Science Communication Medal [see page 70]. A big thanks goes to Peter Buchanan and the judges for their efforts.

New Zealand Science Review continues to provide a key outlet for reporting around science policy and ideas. We continue to look at ways to improve delivery and benefit to authors. Thanks go to Allen Petrey and Geoff Gregory along with the NZSR Editorial committee (Hamish Campbell, John Clare, and Mike Berridge) for maintaining and enhancing the quality of this important voice for the Association and for science.

The position of President is a two-year role. It takes a year to work out how the whole thing works – so that gives a year to inject ideas and energy and prepare for the next phase. I have proposed a change to the rules to allow for a co-Presidency, not only to share the burden, but to spread the perspective of the Association leadership. Although the Association feels strong, actual membership numbers continue to be a struggle. Our financial situation would also be marginal if it weren't for the grateful support from the now-defunct Association of Scientific and Technical Communicators through the efforts of Alan Knowles.

We continue to look at ways to either boost numbers and/or change the way the Association works, reflecting changing attitudes to membership and Association utility – Troy Baisden especially is be thanked for his efforts in this and many other fronts.

My sincere thanks, on behalf of membership, goes to Council. This is all done 'on the side' by all of us, along with all the other things 'on the side'. If I had the energy I'd plot up the time-of-day some responses come in via email. Neil Curtis is thanked for his role as Patron, although as noted by all, we haven't really worked out what to do with the role. Fiona McDonald continues her vital secretarial/organisational duties, Chris Bumby wrestles with the accounts, Troy Baisden provides ideas and energy, Nicola Gaston and Shaun Hendy provide substantial support, wisdom and experience – especially around working with the media. Peter Buchanan's tireless work to organise the awards is a great deal of effort handled smoothly. Simon Granville provides support around web activity but also much more besides this, with ideas, passion and careful analysis. Mike Berridge, John Clare, and Desmond Darby are as ever, valued, with their wealth of experience around various aspects of the New Zealand science system. I also thank the members of the Association outside Council who also helped out where needed. To those leaving Council, I thank them and welcome new members to take up the mantle. I look forward to the New Year and seeing what we can achieve for New Zealand science.

Craig Stevens
President

* Presented at the New Zealand Association of Scientists' 76th Annual General Meeting held on Wednesday 1 November 2017 at 'Caroline', Manners Street, Wellington

Article

A review of the new MBIE Report on the Marsden Fund

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The New Zealand Ministry of Business, Innovation and Employment (MBIE) has recently completed a report on the way that the Marsden Fund works (MBIE 2017). In many ways this is an excellent document. It describes the history and purpose of the fund and explains how it operates. It also compares Marsden to other granting agencies overseas (Section 3). The authors consulted widely with stakeholders, identified many issues in their findings (Section 4) and made a set of recommendations (Section 5). Although a lot of key points were revealed, the MBIE team seems to have been consistently just wide of the mark, in the estimation of this reviewer. In this short article I identify those key topics that have been a source of long-term concern for many applicants and commentators. It is hoped that these, together with the original MBIE report, may stimulate wider discussion in the scientific community.

Keywords: Marsden Fund, MBIE, assessment panels, funding.

Introduction

The Marsden Fund is an annual competition that provides support for basic (aka blue skies or investigator-led or -initiated) research and, to a lesser extent, applied research. However, there is still some ambiguity in the minds of stakeholders about the *research horizon* actually considered by Marsden (see MBIE 2017, Section 4.3.2 p. 19). The fund started in 1995 with the equivalent of NZD 9 m (in today's terms) and now dispenses around NZD 58 m, rising to NZD 80 m by 2019/20 (see MBIE 2017, Section 1.3 p. 3). It is well known, but perhaps still surprising, to note that even now it can only fund around 7% of applications. The scheme is efficiently managed by the Royal Society of New Zealand. The assessment process is generally felt to be without bias, but is often claimed to be something of a lottery (see MBIE 2017, Section 4.2.4 p. 16). Nonetheless, applicants generally report that the two-stage selection process provides adequate reward for the effort of putting applications together. Overall, the view generally expressed is that getting a Marsden grant is a prestigious event and reflects one's high standing in the scientific community.

In their recent report, MBIE (2017) reviewed all these aspects of the Marsden Fund and, although not entirely buying received wisdom as presented above, they did not ring any loud alarm bells either. Their team arrived at a set of conservative recommendations for improvements together with several proposals for investigation of alternative ways to run various parts of the operation. This latter list is prudent, because not all problems identified are serious ones and not all solutions are either easy or obvious. In the opinion of this reviewer, MBIE has done the scientific community a great service in putting this document together and have touched on most, if not all, the difficulties that applicants have found when trying to secure research support from this source. However, it is my also my view that MBIE has been consistently just wide of the mark in their analysis and thus cannot be said to fully appreciate the frustrations of those they serve. In the sections below I have laid out what I take to be the key issues and some comments on MBIE's approach to addressing them.

Issue 1. The Marsden Fund is massively oversubscribed.

There can be very little argument against the assertion that a 7% subscription rate is much too low, to the very point of being an abuse of talent. MBIE recognises that there are legitimate concerns about success rates (MBIE 2017, Section 4.2.2 p. 15). All things being equal an investigator can only expect to get a grant funded by Marsden about once every 15 years! In other words, if you score two in your whole career, then you are doing OK. The effort squandered on applications is tempered to some degree by the two-stage process with just 17% of first-round one-page proposals succeeding and a generous 44% of second-round full applications receiving support in 2015 (MBIE 2017, Section 4.2.2 p. 15). This shows that a great deal of potentially good science is being starved of resources. MBIE's view that simply increasing funding may not improve the subscription rate (MBIE 2017, Section 4.2.2 p. 15) has some foundation, but cannot be the whole story or else all granting agencies everywhere would have this same rate, as is clearly not the case. True, the Marsden Fund budget allocation has been steadily increasing over the years, but this trend will need to continue for many years to come if investigator demand is to be satisfied. In the paragraphs below I have made some suggestions regarding mechanisms for

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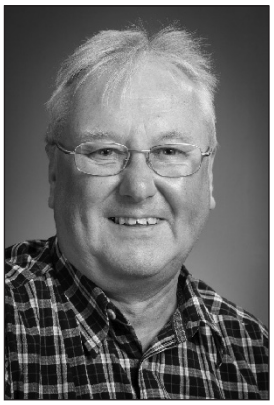

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increasing the available budget and limiting application inflation (see under Issue 4 below).

Issue 2. Marsden awards create a false impression of prestige.

Marsden Fund grants are said to have been awarded by the top science scheme to the best scientists for pursuit of the best science (MBIE 2017, Section 4.2.1 p 15). Rather, it might be nearer to the truth to say that Marsden is not simply the best competitive granting scheme for New Zealand scientists, but that it is the only granting scheme available to most scientists. Let us now unpack that idea that the scheme selects only the best of the best. In the second round and after extensive international review, Marsden panels find it hard to rank second-round applications (MBIE 2017, Section 4.2.2 p. 16). Of course, this also means that the other 56% of the full applications in 2015, which were also good science, went without funding. The same fact may be used to support the idea that at least the panel got something right in the first round, or at least they were able to screen out applications that would have diminished our national reputation if they were sent overseas. I think that many recognise that some people have a particular talent for drafting good first-round applications. Such skills are now widely coached and nurtured by host institutions (MBIE 2017, Section 4.2.4 p. 16). However, I think that many also recognise that many good scientists cannot manage to put convincing one-pagers together. Further, that what is described in the successful one-pagers may not be exclusively the very best science we have on offer. Set against this proposition are the statistics on publication success by Marsden recipients, showing that they do perform above the norm in this regard (MBIE 2017, Section 4.1 Figure 3 p. 15). I concede that this is an index of achievement, but I caution that getting a paper into the top 10% of journals (e.g. as ranked by Impact Factors etc.) does not mean that individual papers are actually in the top 10% of science. Overall, one is led to the view that Marsden grantees are doing rather well, but one would still need to see data on numbers of publications and patterns of submissions to be certain. Hence, if one concentrates all one's efforts on just one paper per year and only ever submit them to journals in the top 10%, then one's Impact Factor rating is always going to look pretty good, even if it does come at a cost to productivity.

Issue 3. Applicants have near-endless concerns over fairness.

MBIE captures this angst very effectively and includes detailed analyses of Round 1 and Round 2 assessment procedures and makes some thoughtful recommendations to improve transparency (MBIE 2017, Section 5.2 Recommendation 4 p. 32). I am surprised to learn that many applicants think that Round 2 is a lottery, when I had always thought that this descriptor applied more exactly to Round 1. However, given that most applications that enter Round 2 are potentially fundable and hard to rank, then I am inclined to have some sympathy with their claim.

So is it fair to call the Round 1 process a lottery? It is certainly burdensome for assessors (MBIE 2017, Section 4.5.5 p. 23), but do they deliver an equitable outcome from all this hard work? For a long time I have believed that it was unsupportable to allow Marsden panellists to make the seemingly ludicrous claim that they could fairly rank 120 applications in the time available to them. I have softened this position somewhat of late on the understanding that the task is not much worse than marking 120 student essays. Never an easy task, but by no means impossible. Also, it is widely held that best applications are easy to pick and the worst can quickly be weeded out. There are no figures available regarding the proportion of this latter category and it is perhaps surprising that such poor-quality products are sent in at all. Overall, confidence is improved by recognising the reported consensus of panellists regarding the very top applications and the fact that one-page proposals sent down to the second round seem to result in high-quality full applications. This reviewer would be very interested to learn what would happen if a year's worth of Round 1 applications were to be scored blind by a second independent panel of assessors.

Alternative approaches have been suggested, including limiting the number of applications to each panel from institutions and/or individuals and more efficient panel structures and processes (MBIE 2017, Section 4.5 p. 21). One alternative would be to assign only a limited number of applications to each panellist. This system was used in previous years, with just three panellists reporting on each Round 1 application. This has been dropped in favour of the present more stable and representative system with each panellist with no conflict of interest ranking all applications, workload and read-through quality notwithstanding. The earlier three-panellist system scoring via 'Yes', 'No' and 'Maybe' was clearly open to abuse, as a rival could be stymied simply by one conflicted person voting 'Maybe'. I am not for one minute suggesting that this actually happened, but the widespread conception that it could happen was corrosive to morale.

Issue 4. The Marsden Fund carries illegitimate financial burdens.

Specifically, these are staff salaries (aka FTE quota) and overheads for those applicants employed in tertiary institutions. This has the effect of making the awards too small (MBIE 2017, Section 4.6.1 p. 25). Many successful investigators report that fully funded grants only run to the employment of just one postdoctoral fellow and possibly some support for an associated PhD student. MBIE's solution (MBIE 2017, Section 4.6.4 p. 27) is to increase the size of the awards – a welcome suggestion to many perhaps, but it must come at the cost of reducing subscription rates below even the present 7%, unless the total fund pool can be increased. To my mind, this practice of claiming FTE contributions and overheads is double-dipping in its most naked form, because these are supplied by TEC via bulk funding and PBRF allocations up to 0.4 FTE (being the notionally agreed fraction of university staff time available for research). Marsden Fund applications have no requirement for applicants to show how this 0.4 FTE is allocated, which absolutely is necessary to make any sort of case for a buy-out of teaching time (also notionally 0.4 FTE) or perhaps from the remaining 0.2 FTE which is supposedly devoted to administration, enhancing the scientific environment, and public engagement. Even given that a scholar can make a case that 0.4 FTE of his/her time is already committed to funded research projects, then claiming further resources to buy out of teaching time means that they will be replaced in the classroom by a younger, less experienced (and perhaps less qualified) teacher. This seems to go against the central mission of our universities to provide programmes of instruction from those experienced and actively engaged in research.

There is one special category where providing an FTE schedule should be mandatory and that is for individuals involved in Centres of Research Excellence (CoREs). The central idea of CoREs was to free up a small clique of top researchers from the treadmill that is the reality of life for those seeking to fund costly projects. Since their inception, many fear that the founding members of CoREs have become super-competitive predators using CoRE-funded research findings as seed data for Marsden projects. Hence, they may be seen as better positioned to claim an unfairly large slice of the funding pie. Some CoREs (e.g. the late lamented Allan Wilson Centre) have developed into networks of necessarily lesser research excellence. In many ways, one might commend these developments as being more democratic, but it does dilute the CoRE objective. Either way, CoRE members really do need to declare their FTE funding and list their pre-existing projects to Marsden in the interests of transparency and equity.

Like FTE quotas, overheads were introduced partly to satisfy the anxieties expressed by CRIs regarding the need for *level playing fields.* Their concern was that universities would undercut them by bidding lower for the same piece of work. The CRI staff had no option, but to include these costs due to the alarmingly commercially competitive environment that they had suddenly found themselves operating in. This drain on the Marsden Fund pool never needed to happen if applications from the two sources had been treated differently and it was made clear that the bottom line was not a factor in decisions. The exception to this suggested rule change would be for new staff, e.g. Postdoctoral Fellows newly recruited to carry out Marsden projects. Here it would be unfair to ask universities to carry the cost of researchers they had not budgeted for.

In its original from, as first introduced to the New Zealand scientific community by Professor Ian Axford, the Marsden Fund did not allow FTE and overheads to be charged. This was supposed to be all new research money, pure and simple, which was all going to go to the investigators. Well now it does not. A sizeable chunk of the money goes to the university for FTE and overheads. One might legitimately ask what they do with it all. This is a fair question, and these are public funds after all. I believe it would be legitimate to ask for a full accounting and justification. In the interim, I strongly recommend dropping FTE and overhead components of Marsden Fund grant budgets for both universities and CRIs. This is now justifiable in the latter case because CRI managers now receive some bulk funding that potentially could be directed to these ends.

The above matters are important and deserve urgent attention. Dropping the FTE and overheads items will automatically increase the available budget and improve the 7% subscription rate. Managing individual FTE budgets will help to ensure that staff are not overworked and automatically limit the number of applications that are submitted. Together these reforms will give everyone a better chance of getting some support for their work.

Issue 5. What is the Marsden Fund for?

When the Marsden Fund was delivered to potential applicants by Professor Axford he explained that the New Zealand Government had bought into the idea that applied research projects (i.e. what the CRIs did) were most successful when underwritten by a 5 to 10% investment in basic research in the same area. The MBIE Report addresses this concept (MBIE 2017, Section 5.2 Recommendation 3 p.31) by thinking about alignment with their *National Statement of Science Investment* (MBIE, 2015). In the event, Marsden has gone its own way and funds many good projects quite unrelated to the various CRI missions. The report also includes various fine-sounding descriptions about what the higher objectives of the Marsden Fund might be. In general, these appear laudable, but seem rather vague and difficult to pin down. I would prefer to think of the Marsden Fund as aiming to be a fair way for all scholars to obtain some much needed research funds.

Issue 6. The fund manager has a serious conflict of interest.

The Marsden Fund is run by the Royal Society of New Zealand (RSNZ) in the sense that they function as the secretariat for the Marsden Council. Many, including MBIE (Section 4.2.1 p. 15), seem to feel that they are doing a pretty good job of it. I think that there is no question that they make the trains run on time. In other words, the administration of the fund has continued efficiently over many years. This is a fine achievement. The fund is said to be successful in selecting and supporting high-quality research. However, this really ought to be the case given that only the very top 7% of applications are funded, and these predominantly from scholars with strong track records. It would be hard not to succeed under these circumstances and RSNZ cannot really be said to have added value to the process.

A conflict arises because RSNZ has as part of its mission to husband the Marsden Fund resources carefully, but at the same time also to advocate for the interests of scientists. Hence, it should be up to them to challenge the universities regarding overheads, etc., and to put strong public pressure on the Government to drive the budget up. One might think that taking stands on such matters would put RSNZ at risk of losing their contract to run the Marsden Fund. This would mean their losing the income that comes from managing it. I have never seen any figures for the sort of money involved. I believe that these should be publicly available since these are public funds.

Issue 7. The Marsden Fund does not support continuity.

This feature is recognised by MBIE (Section 4.6.2 p. 25). Amazingly, this is policy. However, it runs counter to common research experience. Investigators often find that one set of experiments opens up new questions along the same lines. Naturally, they want to follow up these productive avenues. Marsden simply does not allow them to do this. Instead, they have to reconfigure the work and disguise it as an entirely new, but bogus, research direction. Surely this is not good practice. MBIE suggests (MBIE 2017, Section 4.6.4 p. 27) funding longer-term projects (say 3 to 5 years), but I believe that it would be better to drop this criterion altogether and simply allow longitudinal investigations. However, I would recommend one exception, namely where a successful research plan is simply repeated in another time or place or organism. This need not be a hard and fast rule, as repetitions can build confidence in a model, but the Marsden Fund should continue look to novelty as one of their prime directives.

Issue 8. New Zealand is intoxicated by the need for hypotheses.

If any reader should doubt this assertion, they should try writing a grant application without one. They are likely to find their proposal rejected and classed as stamp collecting or hobbyist.

This is unfair, as unbounded surveys are still good science and lead to hypotheses. In my view, the reason we like hypotheses is that we were flattered because the great philosopher Karl Popper chose to spend some time in Canterbury. One of his great concepts was that ideas (framed as hypotheses) could only be falsified and not proved. Hence, we now seem to require all grant applications to test a hypothesis to see if it can be falsified. This is nonsense, because an open survey can be converted into a hypothesis simply by guessing what one will find, even better if your guess is suggested by a paper in the scientific literature.

Conclusion

MBIE scores six out of ten at best. The facts are mostly all there, as are some good ideas and suggestions, but they do not quite capture the key problems. I have tried to lay these out above, together with some suggestions for solving them. In this regard, I point particularly to the ideas presented under Issue 4 which could lead to immediate improvements in funding levels and equity provided that the anticipated pushback from the universities can be overcome. I cannot claim to have fixed everything because some of the difficulties are complex and some can't be easily fixed. Nonetheless, I hope that these pages may excite a wider debate around a most important resource for New Zealand researchers.

Acknowledgement

Geoff Chambers is grateful to Victoria University of Wellington for alumnus staff support.

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News

OECD Science, Technology and Industry Scoreboard 2017 – The digital transformation

The OECD Science, Technology and Industry Scoreboard 2017 draws on the latest international comparative data to uncover the strength of the OECD and other large economies, and shows how the digital transformation is affecting science, innovation, the economy and the way people work and live.

Mobility, cloud computing, the Internet of Things (IoT), artificial intelligence (AI) and big data analytics are among the most important technologies in the digital economy today, empowering businesses, consumers, and society as a whole. However, their development and use are distributed very unevenly. The headquarters of the top 2,000 R&D corporations worldwide are concentrated in just a few economies – notably the United States, Japan, and China – and about 70% of their total R&D spending is concentrated in the top 200 firms. Although the digital transformation is affecting all sectors of the economy, Telecommunications and IT services are consistently ahead in terms of digital intensity, while Agriculture, Mining, and Real estate are consistently ranked at the bottom. Significant differences remain in a majority of OECD countries, including between younger and older generations, between women and men, by educational background, urban and local locations, and firms of different size.

This publication aims to help governments design more effective science, innovation, and industry policies in the digital era.

Read more at:

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Article

The Zealandia continent: a worthy replacement for Pacifica?

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Citation analysis for papers suggesting a laterally dispersed continent ('Pacifica') and a submerged continent in the region of New Caledonia and New Zealand indicates sustained preference for the latter, certainly on geological evidence and probably on biogeographic evidence. However, the name assigned by geologists to this entity – 'Zealandia' – is historically inaccurate and politically contentious. A politically acceptable name for the continent that does not kindle post-colonial dissent might be 'Vallardia', reflecting the sixteenth century Portuguese maps of the region, but is unlikely to find favour with historians. A solution to this conundrum is to revive the name 'Pacifica'.

Keywords: citation analysis, New Zealand, Zealandia, Pacifica, politics

Prologue: An apparent obituary for Pacifica

> *Pacifica is barely mentioned in the geological literature today. New data collected since the 1980s has shown that those earlier interpretations were not correct: none of the present-day Pacific Ocean ridges and rises is continental crust, but instead all are thickened oceanic crust.*

With those words in a populist geological reinterpretation of the geology of New Zealand as a part of a much larger continent – Zealandia – Mortimer & Campbell (2014: 116) dismiss the thirty-year-old idea of the dispersal of an earlier proposed continent – Pacifica. This paper traces the development and demise of the idea, largely through citation analysis of the papers in which it was initially suggested. Pacifica's replacement – Zealandia – may be more acceptable geologically, but its nationalistic associations undermine its credibility.

The concept of Pacifica

Fragments of the continent of Pacifica appear to have been first identified around the margins of the Pacific Ocean by two Stanford University staff-members, Amos Nur and Zvi Ben-Avraham; the idea was picked up by Peter Kamp, at that time a PhD candidate and junior lecturer at the University of Waikato in Hamilton, New Zealand. Both of these papers were published in *Nature*, with the earlier briefly titled and concisely written globally focused paper by Nur & Ben Avraham (1977) receiving nearly three times the number of citations of Kamp (1980), which was rather longer (both in title and in the text) and more regionally focused (explaining the origin of a suite of rocks in the eastern part of New Zealand's South Island).

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Citation analysis – Pacifica

Research papers generally show a peak in the number of citations within a few years of publication, and the number of citations declines reasonably rapidly thereafter (Hodder & Balog 1984), the curve resembling a product life-cycle (e.g. Hodder & Hodder 2009). Figure 1 shows that both Pacifica papers generated an initial flurry of interest in Pacifica, which declined to low levels in the mid-1990s.

However, by the mid-1990s, the notion of a continent in the Pacific Ocean that had fractured into numerous fragments of crust (so-called 'exotic terranes') and been transported laterally across the globe to, and come to rest at, the margins of other continents or islands, the remnants being identified in subduction zones in the western and northern Pacific, appears to have become less convincing, prompting van Andel (1994: 163) to comment:

> *The idea of exotic terranes has caught the fancy of many a geologist concerned with the margins of the Pacific, and examples have multiplied like rabbits…. It is not clear just how exotic many proposed terranes really are, nor can it be confirmed that all come from far away. This frenzy to find exotic terranes appears a bit overdone…. but the concept is useful and in a sizable number of cases well documented.*

However, van Andel did concede, 'Continental fragments adrift are not impossible, however; the Seychelles Islands in the Indian Ocean are one example, New Zealand is another.' This assertion may have helped maintain interest in the idea and continued citation of Kamp's paper in particular. There was a second flurry of interest at the turn of the century and a brief spike in 2009. The low numbers of citations (typically 1–2 annually) since 2009 suggest that interest in Pacifica has waned.

The similar citation trend for both papers suggests that their audiences were similar. Based on the titles of the citing articles and on the journals in which they were published, the

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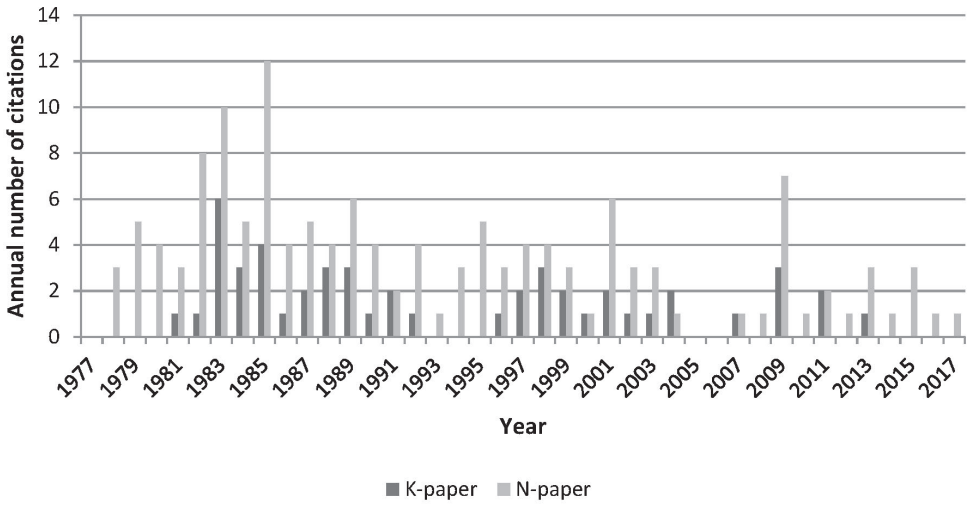
Figure 1. Variation of citations of Pacifica-themed papers with time: 'K-paper' is for Kamp (1980); 'N-paper' is for Nur & Ben Avraham (1977).

Citations for Kamp (1980) compiled from: https://scholar.google.co.nz/scholar?um=1&ie=UTF-8&lr&cites=8495463365729202186.

Citations for Nur & Ben Avraham (1977) compiled from: https://scholar.google.co.nz/scholar?cites=109456357712869662138& as_sdt==2005&sciodt=0,5&hl+en



two papers attracted similar levels of interest in the geological (43%) and biological (56%) research communities. Geologists were interested in the similarity and ages of suites of rocks at the margins of the Pacific Ocean, while the biologists were interested in seeing whether a laterally moving continent or its fragments helped or hindered their explanation of the distribution of fauna and flora.

From the content of the articles, it is possible to determine whether the citing authors agree or disagree with the Pacifica concept, or are neutral, either because they consider that data and information provided are not sufficient or appropriate to lead them to a particular view, or because the purpose of their article is essentially one of presenting the options and choosing not to 'take sides'. From the date of Kamp's (1980) publication, there was always a difference of opinion on the veracity of Pacifica and its application and Figure 2 shows clearly that the number and proportion of negative citations increased with time. This suggests that the decline in the number of citations is caused by increasing scientific disbelief in the concept, rather than being the result of changing fashions in research, which Nicholson (2003: 375-376) has suggested:

> *A very likely reason [for the decline] is that for a decade or so, the terrane concept constituted a fast-moving subfield, attractive to young, imaginative and ambitious geologists. Now that the concept is well-established, avant garde geologists have moved on to more fashionable fields.*

Pacifica lives on

Of course Pacifica was not the first continent in the Pacific for which there was scientific evidence; Nunn (2008: 112) asserted that '… Terra Australis has the distinction of being the first mythical continent in the Pacific whose presence was inferred by science rather than being simply a product of wishful thinking', further observing (Nunn 2008: 113) that:

> *The failure of the search for Terra Australis has not discouraged some people from believing in a large continent in the Pacific. Yet since the continent clearly does not exist above water, then, they argue, it must have become submerged. Often it is termed a lost continent, a number of which have been suggested as lying beneath the surface of the Pacific [Examples described subsequently in the book include a Pacific version of Lemuria (Cervé 1931) and Mu (Churchward 1926).] Yet no such continents do exist. They never did. Nor indeed is it theoretically possible that a continent could sink.*

The inability of a continent to sink beneath the sea is attributed to the relative buoyancy of continental crust relative to oceanic crust, and renders forever unlikely continents that are required to be disposed of by foundering. By contrast, lateral movements of continents are credible; indeed they are an essential feature of plate tectonics. They are convincingly inferred to have occurred throughout most of Earth's past and to continue well into its future (Nield 2007). Interestingly, the notion of lateral continental movements is central to interpretations of the geological history of Tolkien's Middle-earth (Tolkien 1954–1955), whether based on Europe (e.g. Fonstad 1991), or New Zealand (Hodder 2015: 171–205). Taking a more ecocritical perspective, lateral movement of landscape features, especially mountains, are described in New Zealand Māori legends (e.g. Heremia 2017), of which there is wide public knowledge, at least in New Zealand. The idea of 'lateral movement' also resonates with the – albeit controversial – migration and settlement patterns of the peoples of the South Pacific (e.g. Howe 2003; Kirch & Rallu 2007). Thus, despite scientific objections, Pacifica might not yet be as easily dismissed as its vertically foundered predecessors Lemuria and Ur.

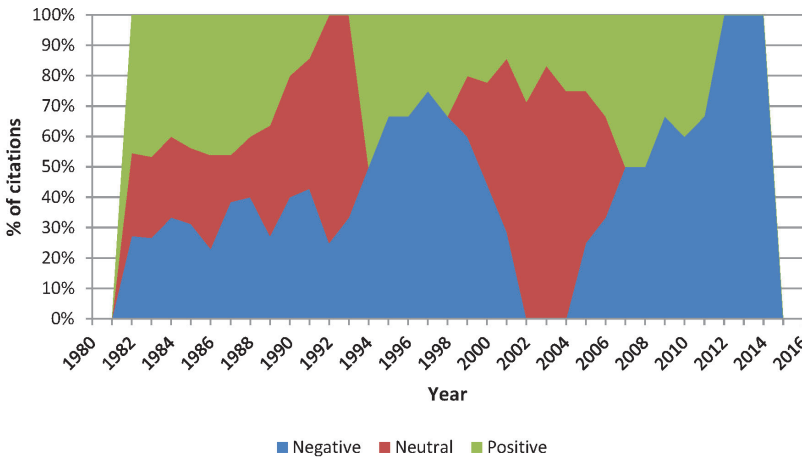


Figure 2. Variation of proportions of negative, neutral and positive citations of Kamp's (1980) Pacifica paper, calculated as five-year moving averages.

Zealandia – a successor to Pacifica?

An alternative to a continent's 'sinking' is its submergence by rising sea level, an explanation advanced in respect of the submerged Yonaguni Underwater Pyramid off Japan (Kimura 2004). Further south, in the New Zealand region, episodic submergence and emergence of land has long been recognised as a feature of its geological history. Even before plate tectonics became pervasive in geological explanations, 'mobile phases' of the landscape, attributed to vertical movements of land and changes of sea level, were central to the overall interpretation of New Zealand geology (Suggate 1978). Numerous paleogeographic maps have shown New Zealand as an archipelago of islands of various sizes and shapes for at least the last 250 million years (e.g. Stevens 1974: 30, fig. 2.1), and have continued to do so.

In a bold move, Nick Mortimer and Hamish Campbell, well-known New Zealand geologists, declared in the preface to their recently published book – *Zealandia Our Continent Revealed* – (Mortimer & Campbell 2014: 9):

> *It is not very often that a new continent is proclaimed… How can a continent have remained hidden until now? Partly this depends on how a continent is defined: geographical or geological? But the main reason is that Zealandia is largely submerged, concealed by the ocean. No wonder it is not obvious. … This new entry in the annals of human discovery is a classic case of piecing together scraps of scientific information and being able to see the big picture.*

Targeted at a public audience, the book includes few references to scholarly works; but this is compensated for by the comprehensive reference list in what might be considered a companion scholarly paper, by Mortimer *et al.* (2017). As was the case with Pacifica, these references portray a 'journey' to developing the concept of Zealandia, which has involved a long period of research using a variety of field and analytical techniques both in the New Zealand region and elsewhere and models of continental crust suture and disruption.

This Zealandia paper does not specifically mention the continent of Pacifica, but does include a disparaging reference to such tectonic reconstructions: 'The importance of Zealandia is not so much that there is now a case for a formerly little-known continent, but that by virtue of its being thinned and submerged, but not shredded into microcontinents, it is a new and useful continental end member.' This view is reiterated in the conclusion to the paper, 'Zealandia is not a collection of partially submerged continental fragments [as was inferred for Pacifica] but is a coherent 4.9 Mkm^2 continent.'

Citation analysis – Zealandia

The paper by Mortimer *et al*. (2017) has already received seven citations, surpassing the initial citation rate of either Nur & Ben Avraham's (1977) paper or Kamp's (1980) paper. Although the numbers of citations are low, the distribution of initial citations by the geological and biological research communities is more weighted towards geologists for the Zealandia paper than was the case for the two Pacifica papers discussed earlier. Not surprisingly, Mortimer *et al.* (2017) refer to earlier papers about Zealandia, and the earliest three of these are used in the citation analysis described below.

Luyendyk's (1995) paper is the earliest reference to Zealandia noted by Mortimer *et al.* (2017): the trend in annual numbers of citations for this paper since its publication is shown in Figure 3. The pattern of citations with time shown in this plot differs somewhat from that in Figure 1, showing a high baseline and reaching its maximum citation count 15 years after publication. Figure 3 also shows comparable plots for two Zealandia-themed papers cited in Mortimer *et al.* (2017) from the mid-2000s, viz. Kula *et al.* (2007) and Mortimer *et al.* (2006). Both of these plots show the typical increase in citations a few years after publication, but both plots also show a resurgence of interest in 2016.

Most papers citing these three articles are positive about the concept of a continent in the New Zealand region, collectively using a range of types of evidence, including paleomagnetic investigations, gravity surveys, and radiometric dating. Figure 4 (an analogous plot to that in Figure 2) suggests that the concept of the Zealandia continent appears to have entered the mainstream of geological thinking to an extent that the Pacifica continent was unable to attain; in that there is a sustained high proportion of citing articles that positively refer to the concept of Zealandia. Moreover, in contrast to both Pacifica-themed papers discussed earlier, very few biogeographers have cited the Zealandia paper, and of those that have done so, most were supportive of the concept. This observation and the citation analysis suggest that in scientific circles the Zealandia continent might persist.

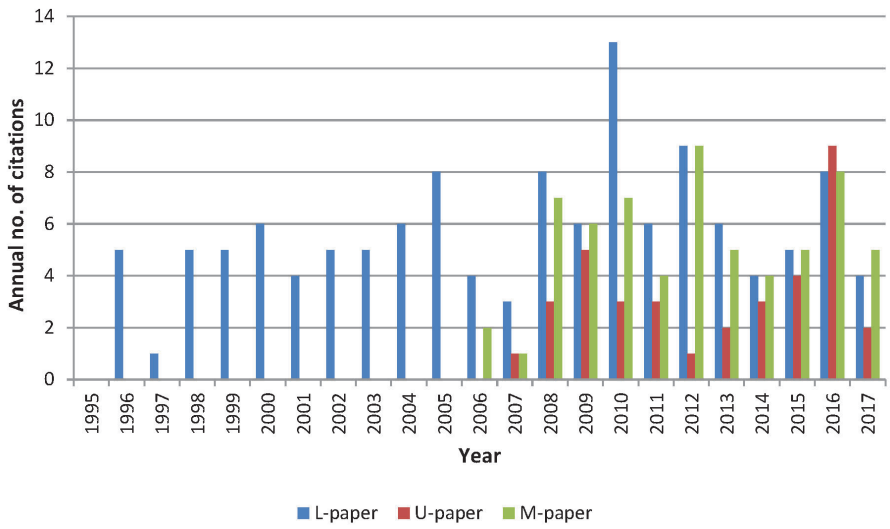


Figure 3. Variation with time of citations for Luyendyk (1995) – 'L-paper'; Kula *et al.* (2007) – 'U-paper'; and Mortimer *et al.* (2006) – 'M-paper'. The L-paper does not include the term Zealandia in its title, but it is included in its abstract; 'U-paper' and 'M-paper' include the term 'Zealandia' in the title.

Citations for L-paper compiled from: https://scholar.google.co.nz/scholar?um=1&ie=UTF-8&lr&cites=12826185231956652222

Citations for 'U-paper' from: https://scholar.google.co.nz/scholar?um=1&ie=UTF-8&lr&cites=3389943439707408427

Citations for 'M-paper' from: https://scholar.google.co.nz/scholar?um=1&ie=UTF-8&lr&cites=16870958545418866542

Political and economic implications of Zealandia

Mortimer & Campbell (2014, p. 9) presented an optimistic view of the political and economic future for island nations that become continents:

> *New Zealand and New Caledonia have gained new identities, new personas, as emergent parts of a sunken continent. The consequences and implications are huge. To be island nations is one thing, but to grow suddenly in stature and take on a continental identity changes everything.*

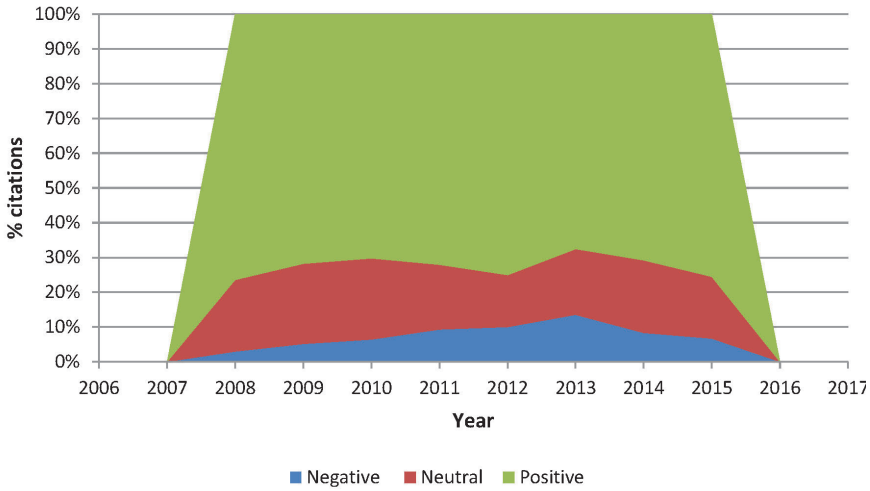


Figure 4. Variation of proportions of negative, neutral and positive citations relating to Zealandia of a combination of papers by Kula *et al*. (2007) and Mortimer *et al*. (2006); all calculated as five-year moving averages

New Zealand's recently expanded exclusive economic zone already includes much of Zealandia (Mortimer & Campbell 2014: 237, fig 5.5). Long-standing interest in the mining of surficial phosphate deposits on the Chatham Rise east of New Zealand (Kearns 1976) has benefited by the expansion of the exclusive economic zone, and the resource certainly offers the prospect of tangible benefits to the agribusiness interests in New Zealand (Chatham Rock Phosphate Ltd 2017), as suggested by previous field trials (Rajan 1987). Similarly, long-standing interest in petroleum and natural gas exploration in the region may be enhanced by the expansion (New Zealand Petroleum and Minerals 2014). It is noteworthy that while New Zealand seems interested in the economic potential for its expanded exclusive economic zone, New Caledonia views at least part of its expanded exclusive economic zone (Radio New Zealand 2015) as part of its conservation estate (Conservation International, undated), raising the prospect of a future debate between New Zealand and France. Although the emergent lands of Zealandia – New Zealand and New Caledonia – have comparatively modest resources of metal ores and other extractive resources, including, for New Caledonia, rare-earth elements (Lesnov 2010: 2-9), the depth of water to the submerged parts of Zealandia is likely to constrain both the exploration for and the recovery of such materials.

Agreement on the northern boundary of New Zealand's exclusive economic zone requires negotiation with the island nations of Fiji and Tonga, as well as with France in respect of New Caledonia.

New Zealand has enjoyed good relationships with Tonga (Campbell 2011, 2015), while in recent decades its relationship with Fiji has been tested by a series of military coups in that country (e.g. Alley 2001; Frankel 2009; Ratuva 2011). Race-based government and the coups' repeated threat to Fijian – and potentially other Pacific nations' – democracy is inconsistent with New Zealand's values and its commitment to Westminster-style politics.

The good relationship between New Zealand and France was strained when France was testing nuclear weapons in the atmosphere above Muroroa (or Moruroa) Atoll in French Polynesia. The replacement of atmospheric testing by underground testing did not diminish New Zealand's concerns, and contributed to New Zealand passing its nuclear-free legislation (Hensley 2013). France's terrorist act of sinking Greenpeace's *Rainbow Warrior* at its berth in Auckland, New Zealand's largest city, in 1985 (Robie 2015) led to an impasse between the two countries, which included mutual trade embargoes. The United Nations ultimately intervened in the dispute, but the relationship between the two countries has taken decades to normalise.

While it is difficult to envisage that political and economic relationships between the nation-states of the submerged continent of Zealandia would be significantly different from that currently occurring between these island nations, 'Zealandia' has been used previously as a term evocative of New Zealand – as described below, and this may have implications for its use in socio-political contexts.

What's in a name?

The use of a female figure of Zealandia on a 1901 New Zealand postage-stamp was 'intended to become a figure of national personification representing the then British colony in much the same way as 'Britannia' represents the United Kingdom' (Stamps NZ, undated). Zealandia was also used as a symbol of nationhood at the Centennial Exhibition in Wellington in 1939–1940, by which time New Zealand had become a Dominion of the British Empire (Figure 5).

However, the name 'Zealandia' bears no relationship to the name of the country; rather, the country is named after 'Zeeland,' a maritime province in the Netherlands. The name 'Nieuw Zeeland' was conferred on the 'land uplifted high' that Dutch explorer Abel Tasman discovered in 1642 by Joan Blaeu, official Dutch cartographer to the Dutch East India Company (Wilson 2016a). To better represent actual history, then, at the very least, the spelling of 'Zealandia' should be changed to 'Zeelandia'. However it is spelt, this name can be argued as too partisan for a continent that Mortimer & Campbell (2014) recognise is the home of other nation-states and territories as well as New Zealand.

Abel Tasman's name was given to the Tasman Sea, which separates New Zealand from Australia, and which overlies 'Tasmantis' – a name for a part of the submerged continent which was revived by Cullen (1969) from its earlier use by Süssmilch & David (1919). Abel Tasman's excursion to New Zealand was brief; a much more definitive New Zealand was established by the British navigator James Cook's circumnavigation of its two main islands in 1769. On Cook's next voyage he discovered New Caledonia, in 1774. Thus, New Caledonia and New Zealand have a shared history of discovery, and this

Figure 5. Certificate of attendance at the New Zealand Centennial Exhibition held in Wellington in 1940. It shows 'a female figure [Zealandia?] partially draped in New Zealand flag, before a montage of New Zealand scenes including Maori whare and canoes, sailing ship and steamship in harbour, woodpigeon and tui on pohutukawa, kowhai, with clematis, manuka, and a kiwi in centre foreground. Edges are a frame of Maori carving and patterns'. [Image: Alexander Turnbull Library, Eph-C-EXHIBITION-1939-01]

suggests that the name of the submerged continent of which they are both emergent islands should reflect that heritage. As a name, 'Cookia' is hardly euphonious, but, more significantly, there are contested views about the effect of James Cook's visit on the lands claimed for the British crown, an example of which is shown in Figure 6. Thus, adopting Cook's name or a variant thereof for the continent would be contentious.

Also likely to be contentious would be a name derived from the sixteenth-century explorations of Portuguese explorer Cristóvão de Mendonça along the west and east coasts of Australia and the North Island of New Zealand – this last inferred by Trickett (2007: 232) to be 'Illa da Magna' – 'Island of Mahogany', portrayed on one of the Vallard sixteenth century maps (Vallard 1547). Although currently identified by Trickett (2007, p. 256) as possibly Tonga, the north-easternmost island on this map, referred to as 'y de Tubaros' in Richardson (2015: fig. 9) might yet be construed to be part of New Caledonia.

The prospect of pre-Tasman excursions in the region are becoming more acceptable, e.g. reference to a book on the subject (Cowie 2015) being added in 2016 to *Te Ara*, New Zealand's 'official' online encyclopedia (Wilson 2016b), but not all historians and scientists in New Zealand and Australia are convinced that the Portuguese were in the area before Tasman and Cook – e.g. Moon 2013; in which Moon's view is unchanged from that presented four decades earlier by Stokes (1970). This is rather a shame, as Mendonsia (a latinised form of Mendonça's anglicised name Medonsa) could have been an appropriate name for a continent that includes both New Zealand and New Caledonia.

Although the precise interpretation of the Vallard maps continues to be debated (e.g. Richardson 2015), the maps themselves *are* physical entities related to the geographic area of the submerged continent. On that basis, 'Vallardia' could be worthy of consideration for the name of the continent. However,

Figure 6. (*Left*) Emmanuel Phillip Fox's depiction of the landing of Captain James Cook at Botany Bay (Australia) in 1770, which was commissioned and painted in 1902. [Image: National Gallery of Victoria, Melbourne: https://www.ngv.vic.gov.au/explore/collection/work/5576/]

(*Right*) Reworking of Fox's depiction, by aboriginal artist Daniel Boyd. His 2006 image has the caption 'We call them pirates out here', and portrays James Cook as 'a pirate ready to take part in the great colonial land grab. Boyd has inserted the faces of his friends as the ship's crew, hoisting the flag whilst Cook surveys the scene with his one-eye. Smoke in the far distance is evidence of an inhabited land in direct contrast to Cook's taking of the land and the later proclamation of it as Terra Nullius [meaning 'no-body's land']'. [Image: Museum of Contemporary Art: https://www.mca.com.au/collection/work/2006.25/]

although the name has no association with colonial activities in New Zealand, New Caledonia or Australia, and France might find the name appealing because it ignores British imperial aspirations in the region, this suggestion is unlikely to be well received by historians.

Epilogue: Pacifica regained

As the first proponents of 'Pacifica', Kamp (1980) and Nur & Ben Avraham (1977) could be considered to have been undertaking a sub-creation, in the sense used by J.R.R. Tolkien in his sub-creation of Middle-earth, viz. 'creating another or secondary world with such skill that it has an 'inner consistency of reality'' (Duriez 2001: 231), most evident in his *The Silmarillion* (Tolkien & Tolkien 1977). Peter Kamp, one of the sub-creators of Pacifica – by virtue of his 1980 paper, cites his own work on this matter only once subsequently (Kamp 1986).

The fall of Pacifica from favour among scientists could again be considered analogous to Tolkien's 'theme of fall as one of the central concerns of his mythology of Middle-earth' (Duriez 2001: 176). However, as readers of *The Lord of the Rings* (Tolkien 1954–1955) know only too well, the success of the hobbits' activities ensured the survival of Middle-earth, both socially and geographically – Tolkien's 'eucatastrophe' (Shippey 2001: 206–212). Kamp took no part in the development of the idea that culminated in the suggestion of Zealandia as a continent, although two more recent papers of which he is a co-author refer to it (Furlong & Kamp 2009; Lindow *et al*. 2016). Nevertheless, if the 'fall' of Pacifica, and the subsequent development of Zealandia are considered part of the same sub-creation, then there is no reason why the term 'Pacifica' could not be revived.

Of course, Tolkien has not been alone in portraying 'fall' and revival; John Milton explored the idea from a decidedly Christian stand-point nearly three centuries earlier in his poem *Paradise Lost* (Milton 1667), in respect of 'the fall' (Compton 2015); and its sequel *Paradise Regained* (Milton 1671), in respect of reinstatement (Dyson 1961). Thus, on at least the basis of Milton and Tolkien, there is an argument for the term Pacifica to be 'regained' as the name for the provisionally named Zealandia.

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Article

K131 Antarctic sea ice science:
A case study of infrastructure, strategies, and skills

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Introduction

If you are fortunate enough to have access to a port-side window when flying into McMurdo Sound, Antarctica, you'll see a long, slender glacier that spills off the south-western flank of Mount Erebus and then floats out into the waters of the Sound. This is the Erebus Glacier tongue, as big as any glacier in New Zealand, but tiny in Antarctic terms. It is also uncommonly narrow relative to its length, and edged by substantial undulations. It has been the focus of research ever since Scott's last expedition, with geologist Griffith Taylor documenting its structure (Taylor 1922). Remarkably, given the decades-long interval between occurrences, the last few kilometres of the glacier broke off during their time there (Stevens *et al.* 2013). The abnormal structure, history of research, and ease of access mean it has been scientifically pored over for decades. It was also the starting point for the development of some Antarctic infrastructure that has been a mainstay of New Zealand sea ice research for more than thirty years.

Ernest Rutherford is supposed to have said 'we don't have much money so we have to think' (da C. Andrade 1964). In the era of ~10% success rates for funding applications, this could be augmented to additionally say 'and be flexible and be prepared to take one's time'. Big science is about big missions, large teams focused on a fundable goal, with its end-points well defined. Certainly, within this envelope, research takes its meanders and, science being science, advances are often found in the side-meanders. What about a different kind of mission? What if the mission is built upon meanders? What if we could go from listening to a glacier through to predicting the impacts of a changing climate?

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K131 genesis

New Zealand's Antarctic science is organised into 'Events', each given a 'K' (for Kiwi) designation. The formative work for one of the better known, and longer-lived Events, K131, took place in the 1980s. Timothy Haskell, then a scientist at the Physics and Engineering Laboratory (part of the Department of Scientific and Industrial Research), along with Bill Robinson and Arnold Heine, developed methods to gauge the Erebus Glacier tongue's inner mechanical workings and how, and why, the tip would periodically calve. This calving phenomenon only occurs every three or so decades (Stevens *et al*. 2013) – hence the point about the good fortune that Scott's party were there to see it happen.

Craig Stevens graduated in civil engineering at the University of Adelaide, and obtained his PhD at the University of Western Australia, subsequently working as a postdoctoral fellow at the University of British Columbia studying environmental fluid mechanics. Dr Stevens is now a physical oceanographer at the National Institute of Water and Atmospheric Research (NIWA) while also being an Associate Professor at the University of Auckland.

Dr Stevens is currently co-President of New Zealand Association of Scientists.

Natalie Robinson obtained her PhD at the University of Otago, specialising in chemical and physical oceanography. She now works as a physical oceanographer at the National Institute for Water and Atmospheric Research (NIWA), where her principle work involves field collection and analysis of data in the Antarctic on a range of ice–ocean processes relating to both sea ice and ice shelf regimes.

Pat Langhorne is an Antarctic sea ice researcher and Professor in the physics department at the University of Otago. She graduated from the University of Aberdeen and obtained her PhD at the University of Cambridge with studies on crystal alignment in sea ice. Dr Langhorne now leads the sea ice observation component of one of New Zealand's National Science Challenges – the Deep South.

Figure 1. A 'ditch-witch' cutting sea ice beams, with the Transantarctic Mountains in the background, 1992.
(Image: T. Haskell)

In the late 1980s, the trio of Robinson, Heine and Haskell spent several field seasons measuring the mechanical response of the glacier to various drivers. It was only a matter of weeks *following* retrieval of their instruments in 1990 that the long-awaited calving event occurred (Robinson & Haskell 1990). Haskell has been recorded as suggesting that, as the strain-meters they were using comprised long wires, the meters may have been holding the glacier tongue together and when removed the glacier fell apart. Here we trace the evolution of the team and infrastructure that evolved from this early Antarctic ice–ocean work. Indeed, Haskell was still involved, two decades later, in work with the team that documented the next, and somewhat earlier than expected, calving of the glacier in 2013 and was acknowledged in a paper on the event (Stevens *et al*. 2013).

Infrastructure as a spine to cross-disciplinary study

The glacier tongue mechanical work naturally led to ideas around the strength of the sea ice surrounding the glacier and its role in protecting the glacier from storm events. This progressed into a project looking at the potential of ocean waves to break up sea ice. The team developed a method to detect the signatures of ocean waves that had travelled substantial distances through sea ice from the open ocean. However, to predict and generalise the effect of these waves, the basic mechanical properties of sea ice needed to be measured.

The team did this by developing techniques for producing ice beams ten metres long, cut from the sea ice during the cool of the spring evening, and then subjecting them to wave-like loading until failure (Figure 1). However, every Antarctic field season brings its own challenges. During the first attempt at measuring mechanical properties, in 1990, the importance of having good infrastructure was revealed and, despite every effort, it was a no-data season. There had to be a better way to work.

A re-thinking as to how field operations could be conducted on the McMurdo sea ice resulted in the birth of the K131 container camp. Insulated shipping containers on sled-skis were converted for various camp tasks and provided a largely weather-proof base from which to conduct work (Figure 2). The camp concept, developed by Tim Haskell and Johno Leitch and fitted out for comfort by Jane Haskell, included containers modified for sleeping, eating, laboratory space – and importantly, a generator. These are deployed by bulldozer in chains, with a single dozer sometimes towing five or six containers. It became a regular sight around McMurdo Sound in October to see the camp being deployed. A line of green boxes inching their way across the sea ice signalled the start of the summer sea ice research season (Figure 3). This first camp was the basis for the diverse variety of research that followed.

The connection between mechanical behaviour and the physics of the ice was explored by developing a team of collaborators with different perspectives on the problem. One of the key environmental factors, apparent even in Scott's time and

Figure 2. K131 in 2016, Transantarctic Mountains in the background. (Image: Natalie Robinson)

Figure 3. K131 container camp being towed to field site using a bulldozer. (Image: Natalie Robinson)

recognised as a possible influence on how the sea ice responded to moving loads, was the layer of platelet ice crystals often found beneath the sea ice. This was the research focus for Pat Langhorne (Otago), a collaborator on the moving-load experiments, who proved to be the scientific thread within the K131 weave, as the container camp proved perfect for development of her work looking at these ice crystals. In a classic example of big science building through linked serial-meandering developments, work looking at individual crystals within ice cores is now looking at ways to observe hidden layers of such crystals from space and then how to connect this with climate prediction.

Sea ice prediction is proving to be one of the leading tasks yet to be reliably resolved with the present family of climate models. However, improving these models is severely limited if the only knowledge on spatial distribution comes from driving around on skidoo and drilling holes. Remote sensing of sea ice extent and thickness is thus crucial to advancing these models. Langhorne brought in collaborators Wolfgang Rack (Canterbury) and Christian Haas (Alfred Wegener Institute, Germany) with air- and space-borne sensor technology to determine sea ice thickness with promising results confirming existing measurements and pointing the way forward for substantial mapping of the nature and condition of sea ice around Antarctica. Understanding the crystal structure *in situ* is required to understand what the satellites are seeing. A sequence of collaborators (Joe Trodahl and Malcolm Ingham from Victoria University of Wellington and Inga Smith from Otago) explored the growth of the sea ice, comparing this with electromagnetic responses, and made comparison with Arctic observations.

Beyond fast ice

Despite the container camp not being particularly designed with marginal ice zone wave studies in mind (one doesn't really want to be in a container on an ice floe moving up and down in swell), Vernon Squire's (Otago) work on waves in sea ice spawned a separate connection to K131. This work always maintained a strong analytical mathematics pathway and is being reinvigorated by Alison Kohout's (NIWA) experiments on waves in pack ice. Kohout conducted her initial tests at the 2012 K131 field camp, learning what needed to be done to substantially develop instrumentation since Squires' first measurements in the 1980s and winter deployments conducted by Haskell and others off the US icebreaker *Nathaniel B. Palmer* in 1999. This preliminary work at the K131 camp proved a basis for ultimate success in deployments from the Australian polar supply vessel, the *Aurora Australis*. The critical point here is that waves might be a pathway for understanding how sea ice will change as climate evolves, since changes to wind patterns may affect how sea ice is broken up (Kohout *et al.* 2014).

The work evolved from ice to ice–ocean interaction through to regional oceanography, and then to climate scales, as there is a growing awareness that the ocean beneath sea ice and ice shelves is crucial to polar environments. The K131 evolution spanned one of the largest geophysical events of the last century in the McMurdo region, with the 2000 massive iceberg calving event that saw several very large icebergs ground themselves to the north of Ross Island. These bergs, amongst the largest ever observed, were originally spawned from the front of the Ross Ice Shelf, and dramatically affected McMurdo Sound regional sea ice and ocean conditions for a decade (Robinson & Williams 2012).

K131 work extended beyond the container camp and included experiments in challenging environments including the marginal ice zone and winter polar oceanography. As well as a winter (1998) voyage aboard the *Nathanial B Palmer*, Haskell, along with Langhorne, designed and supervised two winter-over sea ice campaigns in 2003 and 2009. On each occasion, a post-doc, a PhD student and a field support expert put in the commitment to winter-over (Greg Leonard, Craig Purdie and Johno Leitch in 2003; Andrew Mahoney, Alex Gough and Brian Staite in 2009) to conduct these difficult measurements (Leonard *et al*. 2005, Mahoney *et al*. 2011, Langhorne *et al*. 2015). Throughout all this work, international contributions have been commonplace, with scientists from a range of countries including USA, Canada, Belgium, and Australia all participating in events.

A series of K131 field camps commencing in the mid-2000s saw extension of the facility to include several containers with holes in their floors to enable ready access to the ocean via holes drilled, either mechanically, or with a hot water melter. This was initiated through Mike Williams' (NIWA) integration of full water column oceanography into what had previously been viewed as the boundary condition for ice (Robinson *et al*. 2015). This drove thinking relating to the connection between sea ice and ice shelf cavities. The water beneath the giant Ross Ice Shelf, for example, is around the volume of the North Sea, yet essentially un-sampled. These cavities have been largely excluded from climate models, but we know they are clearly part of the climate system (e.g. Timmermann & Hellmer 2013) and influence coastal margins like McMurdo Sound.

These threads remain in place in a weave with new research components as the K131 team are set to work on several ice–ocean research problems. The 'Deep South' National Science Challenge is a decade-long mission seeking to understand climate impacts on New Zealand with an emphasis on Antarctic drivers of change. Langhorne led sea ice work within the Challenge that connected the remote sensing work with a 2017 *Nathaniel B Palmer* winter voyage. Natalie Robinson, in a Marsden-funded experiment, continued to evolve the K131 infrastructure when she led the 2016/17 and 2017/18 K131 events in search of the fate of the meltwater exiting the Ross Ice Shelf. The 2016/17 event was a double milestone in that it was the first season without Haskell (with Brett Grant of NIWA taking responsibility for keeping infrastructure operating) and it was also the furthest west the camp had ever been deployed. The group pushed the geographic bounds wider through collaboration with Italian and Korean groups working to the north around the Drygalski Ice Tongue, and also to the south with the NZARI-funded Ross Ice Shelf Drill Project led by Christina Hulbe (Otago).

Communication and careers

It is estimated that the K131 Event has produced about 160 peer-reviewed papers in journals or conference proceedings and, at its highest, was publishing one article about every six weeks in refereed journals. Of course, there is a growing recognition that successful science needs to communicate beyond the scientific literature, to the public and other so-called stakeholders. Reasonably enough, science can't expect to tell the taxpayer to 'trust us'; instead, there are growing initiatives to explain what is being done with the resources and why. You can do this with press releases and articles in the increasingly diffuse media. Or, as K131 did, you can do it through what proved to be IRL's highest-demand publication ever. Inspired by a group from the Women's Institute in the UK, who, in support of medical research, produced a calendar combining an absence of clothes with strategically located props (Calendar Girls 2003) – K131 put their own twist on the idea. The Men of Antarctica calendar went through several versions over the late 1990s, gaining recognition in the international media including the BBC weather programme. Production ceased as that sort of activity became common-place, and the impact of slightly blue-looking naked people, with strategically placed field equipment, was lost.

Innovative communication of science for the event was elevated dramatically with the participation of the artist Gabby O'Connor in K131 sea ice camps in 2015/16 and 2016/17 (Barraclough & Findlay 2017, O'Connor & Stevens 2018). Her mission was to both contribute to the scientific data collection, and produce art and art-science crossover work that is at the forefront of STEAM (science, technology, engineering and mathematics, STEM + Art, O'Connor & Stevens 2018). This hybrid approach proved adept at documenting the science in novel ways and resulted in a number of exhibitions and media articles. This was a side-step away from the Antarctica NZ model of artists visiting Antarctica and taking on experiences from an essentially set menu; here, the artist became a protagonist. This was more in keeping with Heroic Era art and science connections – for example, Edward Wilson was a painter – where the artist was a documenter and key element of the promotion machine required to explain results and generate funding and support (Fox 2005).

While the container camp concept is locked into a limited seasonal and spatial range, needing reliable fast sea ice, it has proved a fertile springboard for new ideas and then taking them to more distant locations and seasons. This was especially true regarding the development of long-term oceanographic instrument moorings, which are made difficult by the effects of sub-surface ice growth on the lines. Techniques have evolved so that moorings have now been successfully deployed through an ice shelf, as well as an autonomous ice-tethered profiler deployed near Cape Armitage in 2010, and this dramatically increased the volume of hydrographic data recorded in the McMurdo region for the time it operated. It even became possible to see sea ice grow in real time, with the first K131 sea ice growth web page started by Greg Leonard (Otago) delivering a live feed of sea ice thickness and temperature from the middle of McMurdo Sound.

In earth system science it is often difficult to bring modellers and observationalists together. The fields are so big that individuals who work in the cross-over space are rare, as are workshops where the two approaches are given equal weighting. Instead, both approaches work in parallel and exchange ideas through the imperfect medium of the scientific literature. K131 provided an incubator, through, over the years, bringing leading climate scientists like James Renwick (then NIWA and later Victoria University of Wellington), Sam Dean (NIWA) and Cecilia Bitz (Univ. Washington, USA) to work with field observationalists to get a sense of the challenges behind the measurements and drive future questions for the observations.

Pragmatic innovation was always a specialty of the event. Perhaps in keeping with Hillary's first foray across the continent in a tractor, there has always been a thread of adapting existing technology to the high-latitude conditions. A small bulldozer with a 2m-long chainsaw enabled beams of ice to be rapidly excised (Figure 1). A space-buggy with a clear Perspex housing proved a useful transport vehicle and sun-trap. Milk-sterilising heaters have been adapted to provide water for sea ice hot-water drilling.

The facility also proved a useful incubator for early career development, with many postgraduate students, postdoctoral researchers and early-career researchers passing through the camp. Overall, it is estimated at least 26 students have been associated with the Ki3i Event. This training was critical for the winter field events which teamed a student, postdoc and field support person. With limited contact with senior team members back in New Zealand, these teams rapidly developed an ability to make decisions and operate independently.

Science v. operations

There is always a tension in Antarctic science as to how self-sufficient a science team has to be, from requiring permanent field support in order to survive, through to being entirely independent. The latter approach is more work but ultimately more flexible, and it requires only a few seasons for the science group to have had more experience on sea ice than many of the field support staff. From the outset, K131 sought to be self-sufficient, so that the camp could deploy without on-going field support. Where the operational support is invaluable is in the preparation and surveying of safe travel routes, skilful plant operations with the heavy machinery required to manoeuvre the containers, and occasionally to come and dig the camp out after some particularly deep snow accumulation.

Applications, institutional transitions and funding

Describing the K131 Event as 'serial-meandering' is not a cover-up for 'no plan'. It is essential in order to work over a long period of time on sometimes unfashionable topics (keeping in mind that climate science was once unfashionable) with changing funding. The containerised sea ice camp has survived, and even thrived, through a number of institutional transitions. Initially developed as ideas at the Physics and Engineering Laboratory at DSIR, this became part of Industrial Research Ltd (IRL) with the formation of the Crown Research Institutes in the early 1990s. IRL had a mandate around industrially-relevant topics and initially it was not clear that observing the strength of sea ice, no matter how creative the proposal writing was, would fall within their mandate. However, the decision was made to continue the work, and this faith was rewarded through the K131 collaboration, with Sir Paul Callaghan's group developing portable nuclear magnetic resonance (NMR) techniques.

Callaghan, arguably New Zealand's highest-profile scientist of the early twenty first century, was a strong proponent of linking prosperity to scientific exploration (Figure 4). After an initial planning meeting between Callaghan, Mark Hunter, Bill Robinson and Tim Haskell, held in the latter's sitting room, a good deal of the portable NMR development was based at the K131 field camp. Early tests looked at brine diffusion in McMurdo Sound sea ice, taking advantage of Antarctica's low background noise, and enabled the team to build small, but highly sensitive, instruments (Hunter *et al.* 2009). From there the instruments were reduced in size so that it became possible to build small, portable NMR technology that would work in 'normal' (lower latitude, radiation-filled cities) environments making it possible to take something usually confined to a lab bench into all sorts of domains. This led to the formation of the Magritek company which developed portable instruments to provide nuclear and earth's magnetic field resonance measurements.

There were operational benefits from the science as well. Historically, large transport aircraft used by the US Antarctic Program used ice shelf regions as runways, with the hundreds of metres of ice well able to support the loads as the aircraft landed. However, the possibility of landing heavy transport aircraft on only a few metres of sea ice allows a much wider range of runway choices. A sea ice runway substantially reduces the operations required to support McMurdo Station as it bypasses the road-trip out to the ice shelf runway at Pegasus Airfield, some 40 km away by ice road. At the invitation of Bill Robinson, Vernon Squire (then at Scott Polar Research Institute) looked at how moving loads like a heavy aircraft would spawn waves in the ice, much like the waves generated by a ship moving in water. As with many wave problems, a critical condition occurs when the wave speed equals that of the forcing celerity. Experimental work followed using speeding trucks, and even Hercules aircraft, as the moving load and resulted in a *Nature* cover story based on the original publication (Squire *et al*. 1988).

Another example of the non-linear nature of how science leads to application, is that some of the concepts developed in the sea ice mechanics work led to the IRL-based team, led by Bill Robinson, successfully designing the earthquake lead–rubber base isolators for Parliament, the General Assembly Library, and Te Papa – all in Wellington. K131 outlasted IRL – the Crown Research Institute was reabsorbed into the public service as

Figure 4. Sir Paul Callaghan near Razorback Island. (Image: T. Haskell)

Callaghan Innovation in the mid-2010s. The organisation's role was condensed around being a provider of technical support and funding for industry, somewhat at odds with the outlook of its namesake. This eventually resulted in transfer of the K131 infrastructure to NIWA, the Crown Research Institute with the greatest stake in sea ice-based research at the time, and growing work in the ice–ocean and fisheries/ecosystem themes.

New Zealand's Antarctic research is made possible in the first instance by the Ministry of Foreign Affairs and Trade, which supports the nation's scientific presence in Antarctica, through Antarctica New Zealand. This keeps the operations and infrastructure going. With the changing institutions and evolving science priorities, support for K131 has come from many funding mechanisms. The Marsden Fund supported several K131 campaigns, including its first winter experiment, ocean-driven melting of the Erebus Glacier tongue and, more recently, work towards the western side of McMurdo Sound looking at how sea ice changes with distance from the Ross Ice Shelf. A second winter campaign was supported by dedicated funding for the International Polar Year through the short-lived Ministry of Science and Innovation. At the time of writing, along with NIWA Strategic Investment Funding, the Deep South National Science Challenge, Ministry of Primary Industry/Fisheries and the Marsden Fund are the primary supporters of the K131 legacy. Through this time, the operational support structure for Antarctica also changed. First visits to Scott Base were through New Zealand Antarctic Research Programme (NZARP); this evolved with the formation of Antarctica New Zealand and the evolution of its role in the balance between provision of logistics and assessment of which science to fund. Research funding in Antarctica recently saw the formation of NZARI (New Zealand Antarctic Research Institute), which supported several K131 events, so that philanthropic support held a controlling stake. At the time of writing, a new 'research platform' is being developed by the Ministry of Business, Innovation and Employment, which looks likely to support several sea ice and ocean research threads in the coming years.

The container camp concept has faced challenges beyond funding. Fire is one of the great dangers of Antarctic work – like a ship, shelter is everything. An unoccupied field hut mounted on the tip of the Erebus Glacier tongue was destroyed by fire after the tip broke away in 1990. One of the K131 oceanography

containers was extensively damaged in a heating fire just after refurbishment, and team members witnessed the loss to fire of the Antarctica New Zealand A-Frame hut in Windless Bight during the winter of 2009.

A Strait

In 2009, the ocean passage connecting McMurdo Sound from the substantial oceanic basin beneath the Ross Ice Shelf was named Haskell Strait by the New Zealand Geographic Board Ngā Pou Taunaha o Aotearoa (Harrowfield 2017). The Strait is around 25 km wide and, in places, over 900 m deep (Figure 5). Currents of nearly half a knot have been measured, although typical flows are lower. For comparison, Haskell Strait is as wide as Cook Strait and has through-flow comparable to the Straits of Gibraltar. Although mostly covered by the ice of the McMurdo Ice Shelf and the sea ice of McMurdo Sound, on rare occasions ice breakout exposes the north-west corner of the Strait, which then becomes navigable and vessels have at times moored just off Scott Base. Until sea level rise and

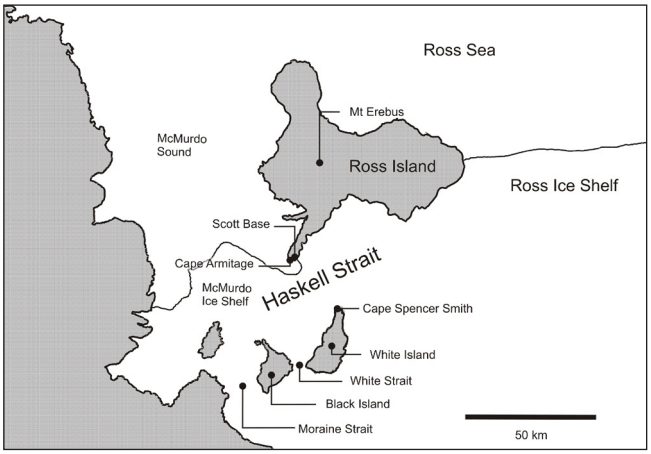

Figure 5. Map showing Haskell Strait in relation to Scott Base and Ross Island.

reduced ice coverage changes the shape of our oceans, Haskell Strait is likely the last strait of its size to be named world-wide. It was presumably previously overlooked, as it is perennially mostly ice-covered and is dominated by the ice barrier (here, the McMurdo Ice Shelf). However, it dwarfs other long-named ice-covered straits in the area – for example Moraine Strait and White Strait, which separate Minna Bluff from Black Island and White from Black Islands, respectively.

The Strait was the scene of great drama during the Heroic Era. Cherry-Garrard's description of the Scott parties' attempts to get themselves and their ponies off disintegrating sea ice, past patrolling orca, and onto The Barrier (the ice shelf) makes for harrowing reading (Cherry-Garrard 1922). While that account sits in the back of the mind of anyone who works in the region, our improving ability to understand and predict sea ice and ocean behaviour makes it ever less likely to happen again.

The strait naming was one of a number of honours bestowed upon Haskell (Figure 6). He has received the New Zealand Antarctic Medal, the Royal Society Hector Medal, the NZ Association of Scientists Marsden Medal and the Royal Society Science and Technology Medal. From the perspective of the polar work, it is rather interesting to read his citation for his 2006 NZAS Marsden Medal. The Antarctic work is barely mentioned. It says:

Figure 6. Tim Haskell in 2013. (Image: courtesy Air New Zealand)

The recipient of this medal for 2006 was Dr Tim Haskell of Industrial Research Limited, Wellington. Dr Tim Haskell has conceptualised, initiated and led a number of novel research programmes over a 35 year period and is an outstanding advocate for science in New Zealand. Dr Haskell's scientific interests have covered a broad range of areas from solar heating, to IT, novel optical devices and Antarctic sea ice formation and decay. He developed the test procedures and equipment for the testing of the base isolators installed in Te Papa – one of the largest commercial contracts undertaken by IRL. His outstanding leadership and work with the Antarctic Research Programme has spanned nearly 30 years, during which time he has kept together a team of researchers from the universities of Auckland and Otago, Victoria University of Wellington, IRL, and NIWA, as well as a number of overseas institutions. One of Tim's most significant leadership roles integrated signal processing, communications, optics and synthetic organic chemistry into an applied research programme. This work arises from collaboration between IRL, the universities of Auckland and Otago, as well as interactions with a number of commercial companies. The team is developing 'all-optical' infrastructure components such as routers, switches, laser sources and amplifiers, for optical networks. Without his initiative, this integration of diverse skills would not have happened. Hitherto unknown materials and techniques have been discovered which it is expected will eventually lead to new industries for New Zealand. In the mid '70s he was instrumental in developing hardware for the DSIR computer communications network. This has led to the creation of one of New Zealand's most successful communications research and development companies. He was awarded a Royal Society Science and Technology Medal in 1996 and has chaired the Environmental Assessment and Review Panel advising the Minister of Foreign Affairs and Trade on Antarctic environmental matters. He has also served on the Marsden Fund Physical Sciences Panel and provides advice to the US National Science Foundation on logistics matters relating to sea ice in McMurdo Sound. In education he has been directly involved with around 20 post graduate students in both optics and Antarctic research, as well as a number of undergraduate projects. He is an author on approximately 100 publications as well as numerous industry reports.

Over the past 30 years, K131 science has developed not only an understanding of the physical processes of how the components of an ice-covered ocean work, but also evolved

robust operational methods for experimentation on ice–ocean interaction. The approach has brought together physicists of many flavours, engineers, mathematicians, oceanographers, biologists, biogeochemists, modellers and artists. It is a demonstration of how to do big science in serial-meandering mode.

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Article

Sleeping with the enemy: Science and the humanities still pass each other like ships in the night*

Roger Bradbury**
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Many complex policy problems will yield to the latest science, so policy wonks need more face time with science nerds, writes Roger Bradbury.

You've seen them all before, likely next to those ghastly management guru books in the airport bookshop. I'm talking about the books that popularise the latest scientific breakthroughs and tell you how they will revolutionise your business. And if your business is policy-making, they promise to revolutionise that too.

Like the endless supply of pop psychology books, they promise you an edge. And like them, thankfully, they have a short shelf life.

We've been promised policy nirvana over the years with catastrophe theory, chaos theory, fractal theory, complexity theory and, more recently, network theory. Malcolm Gladwell[1] made hay with tipping points for a few years in the noughties. We've even had a recycling of sorts, with neural network theory of the 1980s re-emerging as artificial intelligence today.

'Cocktail maths', my mathematician friends call them, and they're right. Good for some banter and one-upmanship over drinks but, ultimately, just froth and bubble.

Such books trade on the twin anxieties of many policymakers: that they have only a faltering grip on their subject matter and that, out there, there might just be someone – usually a Science, Technology, Engineering and Mathematics (STEM) nerd – who actually knows how to handle their problem. If only, they think in their darkest, deepest moments, I had paid more attention in maths class instead of deconstructing Shakespearean sonnets; if only I had done more physics and less ancient history.

Sadly that's not the way of the world. Physics – or history, for that matter – ain't for everyone. But if cocktail maths is next to useless, what's a policy wonk to do?

The answer is simple, even if its execution may have its moments: work across the two cultures of the humanities and sciences. As C P Snow[2] famously elaborated, it can be daunting. It was W H Auden who said, 'When I find myself in the company of scientists, I feel like a shabby curate who has strayed by mistake into a drawing room full of dukes.'

So, shabby curate or not, your first task is to find a drawing room. The drawing rooms are there and the doors are open. The best are the news and commentary pages of the two top science journals, *Nature* and *Science*. There you'll find a lively – and accessible – rolling discussion of the latest science.

Engaging in this way instantly puts you at least a decade ahead of those airport books, and gets you closer to the scientists and mathematicians who might help you with your problem – your second and ultimate task.

Now had you been in these drawing rooms in recent times you would have seen the first glimmerings of a major scientific breakthrough[3] that has huge implications for policymakers. Some very clever scientists discovered that complex systems[4] – the very stuff of policy – show distinctive behaviours well before they change state. But these behaviours are subtle and easily missed.

In the real world, complex systems like traffic networks suddenly jam; financial markets or ecosystems suddenly collapse; people have epileptic seizures or heart attacks; individuals suddenly radicalise into lone wolf terrorists; bushfires surge out of control – and policymakers need to know what to do. In at least some of these cases, the scientists were saying that there would be early warnings of the impending change of state, warnings that would allow pre-emptive policy action that could avert the change.

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This was an astonishing discovery. Before this, we could see some systems reaching a tipping point and changing quickly from one state to another. But we could only be confident a flip might occur once the system had entered a 'tipping zone', by which time intervention was pretty well too late.

It was as if we could only become aware of the waterfall ahead when our canoe was right at the lip of the falls. The new science showed that we could become aware of the waterfall well before we could feel its final pull.

Breathtaking as this discovery is, it turns out that it applies only to a subset, albeit a large subset, of complex systems – those that have alternative stable states. But there are many complex systems that simply might just collapse under unsustainable pressures, and then be replaced by essentially new systems. Think catastrophic climate change or the collapse of the European Union. We need to ask: Do *all* complex systems show early warning of a change of state?

This is known as the *Cassandra problem* in complex systems science – how to foretell a coming catastrophic change in a system when everything appears to be going smoothly. And in a new book, *Introduction to Transfer Entropy*, Terry Bossomaier[5] and his colleagues provide an elegant and definitive answer. They discuss a new way of measuring the behaviour of complex systems – a measure, in their jargon, called transfer entropy – that allows just such prediction.

This takes the tipping point story to its next stage. It is indeed 'tipping points for the rest of us', and so is necessarily of great import for policymakers. But it is also necessarily a highly technical work – we are dealing with complexity in all its richness after all. So I can't recommend it to the average policy wonk.

Instead, I urge you to make an offering across the two cultures: buy a copy of the book for a friendly scientist or mathematician, and get into a discussion on how this new approach might help you get a grip on your policy problems. It could be the most exciting thing you do all year.

Footnotes

1. Malcolm Gladwell (2000). *The Tipping Point: How little things can make a big difference*. Little, Brown and Company. ISBN-13: 9780316316965
2. Snow, Charles Percy (2001) [1959]. *The Two Cultures.* London: Cambridge University Press. p. 3. ISBN 0-521-45730-0
3. Marten Scheffer *et al.* (2009). Early-warning signals for critical transitions *Nature 461 (03 Sept)*: 53–59.
4. New England Complex Systems Institute. http://www.necsi.edu/
5. *See* https://www.amazon.com/Introduction-Transfer-Entropy-Information-Complex-ebook/dp/B01N00HCCN

News

The 2018 Rhodes Scholars-elect

Prestigious Rhodes Scholarships* have been awarded to three outstanding young New Zealanders to carry out postgraduate study at the University of Oxford (UK). The 2018 Rhodes Scholars-elect are: Jean Balchin from the University of Otago, Jamie Beaton from Harvard University, and Marco de Jong from the University of Auckland.

Jean Balchin, aged 23, studied at Waihi College, and is completing a Bachelor of Arts Honours in English Literature at the University of Otago.

Jean's passion is science communications. As an intern with the Science Media Centre, the country's independent source of information for the media on all issues related to science, she wrote *A History of NZ Science in 25 objects*. In addition, Jean is an accomplished pianist, exhibited artist, a performer and has a green belt in Judo. She is also an active volunteer with the Life Matters Suicide Prevention Trust and contributed to the *Break the Silence* series on youth suicide run by the *New Zealand Herald* earlier this year.

At Oxford she proposes to study for a Doctor of Philosophy (DPhil) examining Social Darwinism. She says his theory of competition has been perverted to explain and justify status inequalities between different ethnic groups. She proposes a future career in education or academia.

Jamie Beaton, aged 22, studied at King's College in Auckland and graduated from Harvard University in three years with a double degree in Applied Math and Economics as well as a Master of Science in Applied Math.

While an undergraduate, Jamie founded Crimson Education, which provides international and domestic university admissions consulting, tutoring and career mentorship and is now the largest personalised education company in the Southern Hemisphere. He recently participated in the United Nations High-level Political Forum on Sustainable Development (HLPF) looking at alleviating poverty.

While at Crimson, Jamie has observed the powerful disruptive impact of technology, including digitisation, artificial intelligence, and automation and how it is reshaping industry. This has influenced his decision to pursue a Master of Philosophy/Doctor of Philosophy (MPhil/DPhil) in economics at Oxford, focusing on the impact of automation on labour markets. In particular, he wants to 'leverage Oxford's global leadership in the impact of technology on the working world from the Oxford Martin Programme and economics faculty'.

Marco de Jong, aged 22, studied at Auckland Grammar, before completing a Bachelor of Arts (Honours) and is currently completing a Master of Arts at the University of Auckland.

Marco's Samoan ancestry has helped him find a passion for the Pacific. He is currently learning gagana Sāmoa. With others, he formed and energised the University's History Society, of which he is currently President. Through the school's outreach programme he has visited 50 schools, engaged with low decile schools and encouraged Pacific students to study Pacific history. He is also a Tuākana, mentoring all undergraduate Māori and Pacific history students, which has made a huge difference for dozens of students.

At Oxford, Marco proposes to study for a Doctor of Philosophy (DPhil) under New Zealand historian and fellow Rhodes Scholar, James Belich. He proposes to focus on climate change diplomacy and wants to become a force for the Pacific people through either education, academia or diplomacy, to ensure decisions are made with, and not for, islanders.

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*A Rhodes Scholarship provides transformative opportunities for exceptional all-round students to carry out postgraduate study at the University of Oxford. In founding the Scholarship, Rhodes aimed to develop outstanding leaders who would be motivated to 'fight the world's fight', 'esteem the performance of public duties as their highest aim', and promote international understanding and peace. Today, 95 scholars are selected from 64 countries to join the worldwide Rhodes Scholarship community while at university, and throughout their lives.

Further information on the Rhodes Scholarships for New Zealand is available at:

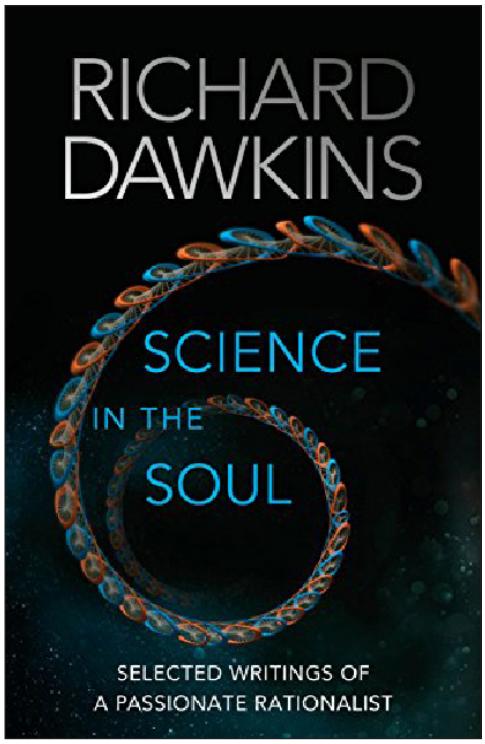
http://www.universitiesnz.ac.nz/scholarships/rhodes-scholarship

Book review

Richard Dawkins

Science in the Soul: Selected Writings of a Passionate Rationalist

Reviewed by Geoff Gregory



As the century drew to a close, Richard Dawkins, the only scientist among invited lecturers to a BBC feature on 'What will the 20th century leave to its heirs?', bewailed the 'hijacking by pseudoscience and bad science fiction [that] is a threat to our legitimate sense of wonder' as are the 'wacky 'personalities' … performing funky tricks to show that science is fun, fun, fun'. He also considered that 'the twentieth century ended with approximately the same level of supernatural credulity as the nineteenth, and rather more outright hostility to science'. This talk is one of forty-one of his essays, speeches, and articles produced over the last three decades and brought together in this anthology.

It does not, however, consist of a set of gloomy prognostications. Following the format of his earlier anthology, *A Devil's Chaplain* (2003), it could easily have borne the same subtitle: '*Reflections on hope, lies, science, and love*', as it encompasses many of the same themes: expressions of his continuing sense of wonder at the natural world and his belief in the positive role of the scientific way of thinking in human affairs; and messages of hope for both a spirituality untainted by the 'infantile babblings of religion' and the further evolution of human values to outlaw prejudice, abuse, and violence towards each other and our animal relatives. He scotches systems of mind control by 'superdumb' religious beliefs, the 'tyranny of the texts', the hypocrisy of their 'cherry-picking' exponents, and the notion of a supernatural, disembodied soul – a 'spook' that survives death of the brain. However, he looks towards science solving the mystery of consciousness and the launching to 'undreamed-of heights' of the soul as he interprets it – the seat of intellectual power, sensitivity, and emotions.

Since *A Devil's Chaplain*, Dr Dawkins has published those beautifully descriptive books on evolution, full of intriguing examples and insightful analogies, *The Ancestor's Tale* (2004, 2nd edn with Tan Wong 2016) and *The Greatest Show on Earth* (2009), and his spirited, polemical book on religion, *The God Delusion* (2006, 10th anniv. edn 2016).

In between, he has written prolifically in support of atheism and reason and rationality in human affairs. In *Science in the Soul*, editor Gillian Somerscales has undertaken the enormous task of reading and selecting representative samples from this *embarras de richesse* of shorter pieces. She precedes each of the book's eight sections with an erudite and sensitive introduction, and Dr Dawkins, unwilling to change what he originally wrote, has brought the pieces up-to-date with footnotes and afterwords.

The first section, on values, covers not only the fundamental scientific value of objective truth and the need to reserve judgement in the absence of evidence, but also the responsibility to society to warn of the possible unfortunate consequences of truth-seeking. It also encompasses the evils of eugenics, racism, and speciesism. Discussing the origin of good values in the face of the teachings of an evil Jehovah he speculates about the future evolution of the 'shifting moral zeitgeist' which has successively illegalised the slave trade, bear baiting, burning at the stake, genocide, and wholesale bombing of cities, and hopes it will include morally abhorrent practices associated with keeping livestock.

The next section constitutes a primer on evolution by natural selection, and includes reasons for the inadequacy or falsehood of alternative proposals. In this and a later section entitled 'The sacred truth of nature', Dawkins is arguably at his best, with

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Published by Penguin Random House
Audio, narrated by Richard Dawkins and Lalla Ward, duration 14 hours 41 minutes downloadable at:
https://www.audiobooks.com/audiobook/9780525495703?ref=cj

*Geoff Gregory is a semi-retired science editor, formerly in the Department of Scientific and Industrial Research.

fascinating tales of the weird and the wonderful in the world. Incidentally, he likens giving support to basic science for its spin-offs, for example space research for the development of non-stick frying pans, to supporting music for the exercise it provides for the right arm of a violinist!

Elsewhere he sounds off about some of the artificial constructs often applied to educational attainment, social situation, political beliefs, the legal system, bureaucratic rulings, and, of course, religious designation. He has a knack of coining such satisfying phrases as 'dimwitted dundridges', 'Brexit-blighted Blighty', 'politicians who flaunt their ignorance as a vote-winning virtue'.

As might be expected, a large part of the book is about religion and atheism. He is forthright in his criticisms of the 'time-consuming, wealth-consuming, hostility-provoking, fecundity-forfeiting rituals of religion', and the evil nature of the God of the Abrahamic texts. He tries reason, iconoclasm, and even satire (e.g. an article about the delusional drug 'Gerin oil' – get it? – responsible for all manner of wars and atrocities). It might surprise religious devotees that, in a piece entitled 'Atheists for Jesus', he writes in praise of the 'superniceness' of Jesus and his 'genuinely original and radical ethics', speculating that human superniceness, which seems a 'perversion of Darwinism', might be spread like an epidemic through *memes* (a term, now widely used on the internet, that was coined by Dawkins in *The Selfish Gene*). His anger comes over in an article about the terrible tsunami in Asia in 2004, for which religious explanations have ranged from 'loopy' (payback for original sin) to vicious (sent to try our faith). Science knows how this happened and can give warning about such events. He writes: 'If a small fraction of the tax breaks handed out to churches, mosques, and synagogues had been diverted to early warning systems, tens of thousands, now dead, could have been moved to safety'.

Finally, there are tributes to Dawkins' father and an uncle, to his Oxford mentor, Niko Tinbergen, to friend and writer, Douglas Adams (as a foreword to his book *Last Chance to See*), and to friend and 'intrepid warrior for truth', Christopher Hitchens, to whom the current volume is dedicated.

Dr Dawkins remarks that it is high time that the Nobel Prize for Literature was awarded to a scientist, such as Carl Sagan, Loren Eiseley, and others. Dawkins himself, who writes with such elegance and incisiveness for a broad audience, should perhaps be a candidate.

News

Release of Stage 2 of Havelock North Drinking-Water Inquiry

Stage 2 of the Inquiry into Havelock North Drinking-Water has been released by the Department of Internal Affairs. Stage 1, which addressed the causes of the water contamination incident and assessed the conduct of those responsible for providing safe drinking water in Havelock North, had been released in May 2017.

The Inquiry was set up in September 2016, following the widespread outbreak of gastroenteritis in Havelock North in August 2016, with more than 5000 people falling ill.

Its members were Hon Lyn Stevens QC (chair), Dr Karen Poutasi CNZM and Anthony Wilson ED.

The main findings of Stage 1 included:

- Sheep faeces containing campylobacter were the likely cause of the outbreak. The Te Mata aquifer was not confined (as was assumed prior to the Inquiry's process) and was vulnerable to contamination.
- Several parties, particularly the Hawkes Bay Regional Council (the Regional Council), the Hastings District Council (the District Council), and the Drinking Water Assessors (DWAs) failed to adhere to the high levels of care and diligence necessary to protect public health.
- The Regional Council failed to meet its Resource Management Act responsibilities and to take specific and effective steps to assess contamination risks to the Te Mata aquifer (from which Havelock North's water was drawn).
- The District Council did not embrace or implement the high standard of care required of a public drinking water supplier, or adequately supervise the implementation of tasks, plant management and equipment maintenance, and had no Emergency Response Plan (contingency plan).
- There was a critical lack of collaboration and liaison between the Regional Council and the District Council, and the DWAs should have been stricter in ensuring the District Council complied with its responsibilities.

Stage 2 addresses systemic issues and provides recommendations about managing water supply across New Zealand to safeguard against such an outbreak occurring in the future.

In light of the evidence it heard, and principles of drinking water supply observed internationally, the Inquiry identified the following six fundamental principles of drinking water safety for New Zealand:

Principle 1: A high standard of care must be embraced
The high standard of care required is akin to that applied in the fields of medicine and aviation where the consequences of a failure are similarly detrimental to public health and safety.

Principle 2: Protection of source water is of paramount importance
Risks to sources of drinking water must be understood, managed and addressed appropriately.

Principle 3: Maintain multiple barriers against contamination
Because no single barrier is effective against all sources of contamination, robust multiple barriers against contamination with appropriate capabilities are needed at each of the following levels: source protection; effective treatment; secure distribution; effective monitoring; and effective responses to adverse signals. A "source to tap" approach is required.

Principle 4: Change precedes contamination
Sudden or extreme changes in water quality, flow or environmental conditions (for example, heavy rainfall, flooding, earthquakes), and change of any kind (for example, personnel, governance, equipment) should be monitored and responded to with due diligence.

Principle 5: Suppliers must own the safety of drinking water
Drinking water suppliers must maintain a personal sense of responsibility at all levels of the organisation for providing consumers with safe water and be able to respond quickly and effectively to adverse monitoring signals.

Principle 6: Apply a preventive risk management approach
The focus must always be on preventing contamination, which requires systematic assessment of risks throughout a drinking water supply from source to tap; identification of ways these risks can be managed; and control measures implemented to ensure that management is occurring properly.

The Inquiry recommended that the six fundamental principles of drinking water safety be recorded and promulgated to the industry and used to inform all recommended reforms, as well as the operation of the entire drinking water system.

The Inquiry's investigations showed that water suppliers in other parts of New Zealand exhibited the same or similar problems to those at Havelock North. The current drinking water regime is fragmented with many different agencies and persons responsible for various aspects of it. The findings point to a widespread systemic failure among water suppliers to meet the high standards required for the supply of safe drinking water to the public. The industry has demonstrated that it is not capable of itself improving when the standards are not met. Neither has the Ministry of Health, the government body charged with administering the provisions of the Health Act governing drinking water, shown an ability to call the industry to account.

There is currently no adequate or effective enforcement of the statutory obligations on water suppliers. The DWAs are underresourced and have not been able to discharge their statutory responsibilities. The important tool of a Water Supply Plan, as used by water suppliers and monitored and enforced by DWAs, has been ineffective to ensure ownership by water suppliers of the risks around the delivery of safe drinking water to the public.

The core elements of leadership identified by the Inquiry lie with the Director-General and the Ministry of Health. In the Inquiry's view, the scale and scope of those leadership elements require proper resourcing. The role of Director of Public Health has been inadequately utilised or recognised by the Ministry of Health in relation to drinking water issues in the past and this should change.

The Inquiry recommended that the Ministry, via the DWAs and Medical Officers of Health, should take urgent steps to administer and enforce the existing regulatory regime. Moreover, pending the creation of a drinking water regulator, a Drinking Water Regulation Establishment Unit should be set up to: maintain momentum; facilitate the establishment of a drinking water regulator; and facilitate the hand-over to a drinking water regulator.

The Inquiry's view is that current knowledge and circumstances call for a much greater level of accountability for drinking water suppliers. It recommends improvements in respect of DWAs and the Health Act, and provision of a dedicated drinking water regulator, together with a licensing and qualifications regime for suppliers to address these aspects of accountability

The full report may be downloaded at:

https://www.dia.govt.nz/Government-Inquiry-Into-Havelock-North-Drinking-Water

The New Zealand Association of Scientists Awards for 2017

The Hill Tinsley Medal*

The Hill Tinsley Medal is awarded for outstanding fundamental or applied research in the physical, natural or social sciences published by a scientist or scientists within 15 years of their PhD.

This year's Beatrice Hill Tinsley Medal is awarded to **Professor Christian Hartinger** from the School of Chemical Sciences at the University of Auckland.

Professor Hartinger is a leading scientist in the fields of medicinal bioinorganic, bioanalytical and bioorganometallic chemistry and is particularly known for his work on the development of metal-based anticancer drugs.

He has pioneered original and creative research strategies, which have led to anticancer agents with novel modes of action, and produced insights into the fate of such compounds in biological systems. His work has significantly improved our understanding of the behaviour of metal-based anticancer agents at the molecular level.

The Shorland Medal

The Shorland Medal is awarded in recognition of major and continued contribution to basic or applied research that has added significantly to scientific understanding or resulted in significant benefits to society

The 2017 Shorland Medal is awarded to the **Fetal Physiology and Neuroscience Team at the University of Auckland**, led by Professors Alistair Jan Gunn (Physiology and Paediatrics) and Laura Bennet (Physiology).

The team, which includes Drs Joanne Davidson and Justin Dean (Physiology) and Professor Colin Green (Ophthalmology), has made an outstanding contribution researching the major causes of death and disability in early childhood, including the identification of compromised fetuses in labour, dissecting the mechanisms of perinatal brain injury, and finding new ways to treat asphyxial brain injury before and after birth.

Professors Alistair Gunn and Laura Bennet

Their most influential work was a series of experimental studies that provided the foundation for understanding how, when and in whom cooling can be successfully used to reduce brain damage in babies. These studies have established cooling, a simple, practical and safe therapy, as the first treatment that significantly improves survival without disability after brain injury at birth.

The Marsden Medal

The Marsden Medal is awarded for a lifetime of outstanding service to the cause or profession of science, in recognition of service rendered to the cause or profession of science in the widest connotation of the phrase.

The 2017 Marsden Medal is awarded to Emeritus Professor Carolyn Burns CBE FRSNZ from the Department of Zoology at the University of Otago.

Professor Burns is internationally renowned for her research into freshwater ecology, especially that of the large lakes of the South Island. A recipient of the Naumann-Thienemann Medal, the world's top award for limnology, she has had a stellar academic career.

She has contributed her scientific expertise to conservation, for example as the Regional Councillor for Australasia and Oceania on the IUCN (World Conservation Union), as well as a long-serving member of two statutory authorities that provided advice to the Minister of Conservation – the Nature Conservation Council (chairing it in 1978–1983), and the National Parks and Reserves Authority.

Her service to science is exemplary, with examples in the assessment of research performance through her involvement on Performance Based Research Fund panels; through the allocation of funds for basic research (with many years of service in numerous roles on Marsden panels); through chairing academic audits of universities around New Zealand; and through the support and promotion of New Zealand scientists by serving on selection panels for a diverse array of prizes, awards and fellowships.

Her leadership has influenced science direction both within and outside universities in roles such as the Director of the Board of National Institute of Water and Atmospheric Research, and as a member of the board of Antarctica New Zealand. Her scientific eminence resulted in her election as a Fellow of the Royal Society of New Zealand in 1993, and she was subsequently the first woman to chair the Society's Academy Council.

(*continued overleaf*)

NZAS Science Communicator Medal renamed in honour of botanist Lucy Cranwell

The Association's Science Communicator Medal, which has been won in recent years by scientists including Michelle Dickinson, Mark Quigley and Simon Lamb, has been renamed in honour of botanist Lucy Cranwell (1907 – 2000), who during a long career spanning much of the 20th century developed a reputation as an engaging science communicator.

Dr Cranwell assumed the role of botanist at Auckland Museum in 1929 as curators prepared to move into its current location above Auckland Domain. She was just 21 and held the position for 14 years, during which time she came up with innovative ways to engage visitors with the museum's exhibits, led field trips for children around Auckland, and found time to collect specimens for the Cheeseman herbarium and write for the *Auckland Star*.

She did extensive fieldwork all over New Zealand before using her knowledge of plants to author a guide to surviving in the Pacific for downed allied pilots during World War II. She later moved to the USA, becoming an internationally recognised researcher first at Harvard University, then the University of Arizona.

Dr Lucy Cranwell

The New Zealand Association of Scientists Awards for 2017 (*continued*)

The Cranwell Medal 2017

The Cranwell Medal (formerly the Science Communicator Medal) award is made to a practising scientist for excellence in communicating science to the general public in any area of science or technology.

Dr Ocean Ripeka Mercier (Ngāti Porou), of Victoria University of Wellington, is the winner of the 2017 NZAS Cranwell Medal.

Dr Mercier is widely known for her role as the presenter of TV science programme Project Mātauranga, which investigates how Māori people, knowledge and methods work with the scientific community to solve a variety of problems. The programme has had repeat primetime screenings on Māori Television and now broadcasts internationally on NITV Australia.

Dr Ocean Mercier

Ocean's contribution to the public communication of science in this way is part of nearly two decades of research and teaching in physics and in Māori Studies. After becoming the first Māori woman to earn a PhD in Physics, she has developed a unique programme of university lectures and courses that critically examine the sciences from Māori and international Indigenous perspectives with her Alaskan colleague Beth Leonard.

Her multidisciplinary backgrounds and communication skills once prompted Prof Sir Paul Callaghan to call her a 'bridge between [the] worlds'. Her research, teaching, service, public speaking and communication support nationwide efforts to 'unlock the potential of Māori knowledge' and understanding the links between mātauranga Māori and science.

Dr Mercier's sustained practice of communicating a blend of science and mātauranga to a variety of different audiences reveals her as a respected researcher and communicator working at the forefront of this field. Dr Mercier is arguably the public face of mātauranga Māori and science, and a deserving recipient of the 2017 Science Communicators' Medal.

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ROYAL SOCIETY TE APĀRANGI

Gene Editing in Aotearoa workshops

The Royal Society of New Zealand Te Apārangi is encouraging New Zealanders to consider and share their views on some potential uses of gene editing in New Zealand.

To assist the public discussion, it has published two papers that outline scenarios for the use of gene editing for both pest management and healthcare.* A further paper with scenarios for the use of gene editing in agriculture will be published soon, along with a paper examining current legislation and regulation.

As part of the public consultation process, Royal Society Te Apārangi is running workshops on how gene editing may impact on healthcare and pest management for those involved with these sectors.

If you are interested in attending one or both of these workshops in either Wellington, Christchurch or Auckland, please get in touch with Marc Rands from our Expert Advice team to register: marc.rands@royalsociety.org.nz

Wellington | Royal Society Te Apārangi,
Aronui Lecture Theatre
Tuesday 13 March
9:30-11:30am: Gene Editing in Healthcare
12:30-2:30pm: Gene Editing in Pest Control

Auckland | NIWA Auckland, Seminar Room
Wednesday 11 April
9:30-11:30am: Gene Editing in Healthcare
12:30-2:30pm: Gene Editing in Pest Control

Christchurch | Tait Technology Centre,
Kauri Room
Wednesday 21 March
9:30-11:30am: Gene Editing in Healthcare
12:30-2:30pm: Gene Editing in Pest Control

All resources are available from royalsociety.org.nz/gene-editing.

NZAS
New Zealand Association of Scientists

Why not consider joining NZAS?

Members include physical, natural, mathematical and social scientists, and the Association welcomes anyone with an interest in science education, policy, communication, and the social impact of science and technology.

Please complete this form and return it with payment to:

Membership Secretary, New Zealand Association of Scientists, PO Box 1874, Wellington

Name.....Preferred title.....

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NZAS is an independent organisation working to:

- Promote science for the good of all New Zealanders
- Increase public awareness of science
- Debate and influence government science policy
- Promote free exchange of knowledge
- Advance international co-operation, and
- Encourage excellence in science

Member Benefits:

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Full membership	$70
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New Zealand Association of Scientists
PO Box 1874
Wellington

Web: http://www.scientists.org.nz