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gene editing pests

Francis Brian Shorland

ecosystem services approach

solving our freshwater crisis

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Contents

Cover: The goneplacid crab *Pycnoplax victoriensis.* Credit Peter Marriott NIWA

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 this issue of the *Review* we carry a number of interesting and topical papers.

Julie Everett-Hincks' and Mark Henaghan's paper, *Gene editing pests and primary industries – legal considerations,* is a shortened version of their 2018 submission to the New Zealand Royal Society's Te Apārangi Gene Editing Panel established to consider the social, cultural, legal, ethical and economic implications of revolutionary gene-editing technologies for New Zealand.

The Royal Society's multidisciplinary panel, comprising some of New Zealand's leading experts, was convened after the 2015 International Summit of Gene Editing, which noted the impact of regulatory frameworks in determining the speed at which biotechnology moves from laboratory to research to marketed product. The lead author of this paper is well placed to comment on the considerations, drawing upon her experience both as an animal research scientist and one who recently qualified in law.

State of environment (SOE) reports aim to give people a summary of the environment through indicators. When an SOE report is associated with specific environmental goals, it is straightforward to develop indicators from the goals. However, it is difficult when there are no specific goals.

In *An ecosystem services approach to choosing environmental indicators for state of environment reports,* John Dymond and Anne-Gaëlle Ausseil explore the use of an ecosystem services framework to develop a general set of indicators for the land/water environment by considering a full range of benefits humans gain from the environment. Their analysis shows that the national SOE report, Environment Aotearoa, is missing many indicators required to draw a broader picture.

According to the authors, this gap in indicators is a reflection of New Zealand's low population and the limited resources that can be reasonably applied to data collection. However, they consider their analysis has application not only in New Zealand but also in other countries that are similarly data-sparse and face similar issues.

In *Some unremembered chemists: Francis Brian Shorland OBE, PhD, DSc (L'pool), Hon. DSc (VUW), FRSNZ,* the late Professor emeritus Brian Halton has provided insights into the life and work of his former colleague, Brian Shorland. One-time patron of the New Zealand Association of Scientists, Brian Shorland had a distinguished research career and, as a long-serving editor of *New Zealand Science Review,* was a frequent commentator on the changes to the research sector that commenced in the 1980s. One year after Brian's death in 1999, the Association established in his honour the Shorland Medal for lifetime contributions to scientific knowledge.

We report the 2018 Prime Ministers' Sciences Prizes in this issue. Now in their tenth year, the Prizes recognise the positive impact of science on New Zealanders' lives, celebrate the achievements of current scientists, and seek to encourage scientists of the future. The Association congratulates all the prize winners and warmly notes that Jim Renwick, past NZAS president (2009–2011) and Professor and Head of School of Geography, Environment and Earth Sciences at Victoria University of Wellington, has won the 2018 Prime Minister's Science Media Communication Prize.

Allen Petrey
Editor

President's column

Embracing science critics

After a rather quiet 2018 for New Zealand science, 2019 has been busy so far for the Association and scientists in New Zealand. A theme that is visible everywhere is the fusing of academic, educational, science, research & development, commercialisation and business endeavours and the challenges such a blurring of boundaries brings with it. Who pays for science? In New Zealand, the MBIE Science Board agreed to fund all 11 National Science Challenges at the maximum funding amount after the mid-way review at the end of 2018. Amongst scientists this resulted in positive acknowledgment of the Government's long-term commitment to the Challenges (in times of prevailing short-term thinking), yet also resulted in critical comments re the need for inclusiveness and transparency in funding science. The Performance-Based Research Fund[1] (PBRF) results for the latest rounds were released at the end of April. The discussion continues when it comes to the usefulness of PBRF, as many argue one could simply take citation data and get the same distributions. Yet in times when the value of traditional taxonomy of organisms is hotly debated, who could argue against the need for a taxonomy of scientists – what PBRF is at its core? New Zealand never had a more transparent and thorough tertiary research evaluation system than PBRF, and the benefit of PBRF is far more encompassing than purely obtaining the final funding distributions. Does the benefit outweigh the costs, though? This is a rather neo-liberal way of critically questioning PBRF, and especially as scientists we understand that often, for advancement, costs in time, money and other resources outweigh the direct benefits. At the end of July, the Ministry of Education announced the setup of the independent panel that will review PBRF; we shall see if various calls amongst New Zealand's diverse spectra of scientists for redefining research excellence will be reflected in the PBRF review outcomes.

The changing face of science funding has its origin more in general societal transformations, than in changes originating from inside the science ecosystem. Traditionally, government science funding resulted from military demands and nations' desire to provide for their people, which sometimes went too far and resulted in actions based on the illusion of superiority. In times of globalisation and living in a rather peaceful stretch of history, the past strong drivers are diminishing, reducing the 'perceived need' for governments to directly support the sciences. Adapting to alternative science funding also provides opportunities to incorporate ways to critically assess for *science to stay sane enough for society's good*.[2] We live in a world that is powerfully shaped by science and technology, and we are the guardians to ensure that science is used for the good in the world. Let's keep discussing how we can embrace being critical of science, and be science guardians to ensure that we do not go back to the times when military demands and superior illusions dominated decision making.

As an Association, we also critically assess our existence and purpose, and are working through refreshing the Association's Council. At our AGM at the end of 2018 we welcomed five new members on board, making the 2019 Council a large team of 17 people. Charlotte Toma, who has spent a number of years in industry, joined us and took on our membership portfolio. Kate Hannah has been involved with the Association already for several years, and I am very excited that Kate put forward a Council nomination, helping us to communicate the need for inclusion, diversity and kindness is science. Naomi Fleming is in a unique position to engage with society outside the usual science suspects, in her role as Women in Engineering Adviser at the University of Auckland, a role that includes designing outreach activities to encourage more girls to study engineering. Neil Broderick continues the strong engagement from the Department of Physics at the University of Auckland with the Association. And Tumanako Fa'aui (Ngāti Uenukukōpako, Ngāti Whakahemo, Te Arawa, Tonga) brings his interest in the integration of indigenous knowledge systems and mātauranga Māori within western-based methodologies on board. I also like to use the opportunity to thank our retiring Council members Delphine Mitchell, Simon Lamb, and Neil Curtis for their contributions to Council and hope that they will continue to contribute as members of the Association. The retirement of Neil Curtis, our Patron, has led to discussions on the retirement of the Patron's role for the Association. I also would like to use this column to congratulate again our past president Professor James Renwick for receiving this year's Prime Minister's Science Prize for Science Communication. Avoiding the worst effects of a changing climate is probably the most important thing science can do right now at a global level, and James communicates this message wherever he goes. It is fitting that our immediate past President Craig Stevens attended the award ceremony at James' invitation, which nicely leads me to my last thanks for this column, going to Craig for his relentless service to the Association during his term as President, and counting.

We received good feedback having had our conference, AGM and awards ceremony in one long day in Auckland last year. We are looking at a similar arrangement this year. In our Council meetings we discuss frequently the changing times. Although our mandate (being an independent body that stands for and advocates for science and scientists in New Zealand) is as relevant as ever, we need to better understand where we should put in our resources and energy to maintain value to members, by embracing new platforms and societal needs. If this is something you'd love to be part of, drop me a line and consider putting a nomination forward to join Council in 2020. There had been a shift to a strong representation from Auckland on Council, and we invite in particular members from outside of Auckland to put up their hands.

Heide Friedrich
President

[1] https://www.tec.govt.nz/funding/funding-and-performance/funding/fund-finder/performance-based-research-fund/

[2] https://blogs.scientificamerican.com/cross-check/we-should-all-be-science-critics

Gene editing pests and primary industries – legal considerations

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Keywords: genetic modification, gene editing, legislation, policy.

Introduction

To explore the implications of gene editing technology for New Zealand, the Royal Society Te Apārangi convened a multi-disciplinary panel of some of New Zealand's leading experts to consider the social, cultural, legal, ethical and economic implications of revolutionary gene-editing technologies for New Zealand. **This brief academic paper is the opinion of the authors, Everett-Hincks and Henaghan, and it informs and is informed by the work of the Royal Society Te Apārangi Gene Editing Panel.**[1]

Gene-editing technologies use proteins, called enzymes, targeted to cut areas of DNA within an organism's genetic material. This process can modify genes, by enabling different repair information. In the past ten years researchers have developed these technologies to manipulate specific genes with growing precision, revolutionising biological science, accelerating research and offering an alternative tool in human healthcare, pest control and primary production. The bioeconomy is growing rapidly with the profusion of biotechnology products predicted to overwhelm regulatory systems.[2]

Advancement of gene editing technologies provides an opportunity to review current regulatory frameworks and devise a future-proof framework to keep abreast of rapidly advancing biotechnologies. The Hazardous Substances and New Organisms Act 1996 (HSNO Act) is the core legislation in a regulatory framework for gene editing technologies. Two decades have passed with minor amendments to HSNO Act. The HSNO Act never contemplated CRISPR-Cas gene editing technology, and might have, if a Commission on Biotechnology had been established to provide a horizon scanning function, as recommended by the Royal Commission on Genetic Modification in 2001. Open, honest and inclusive debate is required on whether *gene editing* is *genetic modification*.

The HSNO Act defines *genetic modification*[3] and provides Regulations for when organisms are *not* genetically modified.[4] Organisms are not genetically modified when they result solely from: selection;[5] or from mutagenesis using chemical or radiation treatments that were in use prior to July 1998;[6] or by the movement of nucleic acids using physiological processes;[7] or spontaneous deletions, rearrangements and amplifications within a single genome.[8] With the discovery of CRISPR-Cas gene

[1] Members of the Royal Society Te Apārangi Expert Gene Editing Panel <royalsociety.org.nz/major-issues-and-projects/gene-editing-in-aotearoa/gene-editing-panel/>.

[2] Preparing for Future Products of Biotechnology. 2017. National Academy of Sciences. The National Academies Press <www.nap.edu/24605>.

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[3] HSNO Act, section 2(1) *genetically modified organism* means, unless expressly provided otherwise by regulations, any organism in which any of the genes or other genetic material—
(a) have been modified by *in vitro* techniques; or,
(b) are inherited or otherwise derived, through any number of replications, from any genes or other genetic material which has been modified by *in vitro* techniques.

[4] Hazardous Substances and New Organisms (Organisms Not Genetically Modified) Regulations 1998 (SR 1998/219). <www.legislation.govt.nz/regulation/public/1998/0219/latest/DLM255889.html>.

[5] SR 1998/219, r 3(a).

[6] SR 1998/219, r 3(ba).

[7] SR 1998/219, r 3(d).

[8] SR 1998/219, r 3(e).

Julie Everett-Hincks was appointed Science Manager at Otago Regional Council in 2019. Prior to this, Dr Everett-Hincks was Senior Scientist for Innovative Farm Systems and Animal Genomics Groups at AgResearch, Mosgiel and earlier the Programme Manager for the Land Strategies Group at the Southern Institute of Technology, Invercargill. She is the 2016 recipient of the Sir Arthur Ward award, presented by the New Zealand Society of Animal Production, acknowledging her work on lamb survival. In 2017 she graduated LLB from Otago University, and until 2018 was Legal Advisor for the Royal Society Te Apārangi's Gene Editing Panel while working with co-author Professor Mark Henaghan as a legal researcher. In October 2018, Dr Everett-Hincks was appointed by the Minister of Agriculture to the Veterinary Council of New Zealand for a three-year term.

Mark Henaghan is a Law Professor at the University of Auckland and formerly long-serving Law Dean at the University of Otago's Law School. He is also a Fellow of the Royal Society of New Zealand. Professor Henaghan was the principal investigator of the Human Genome Project funded by the New Zealand Law Foundation to analyse the scientific, legal, tikanga Māori, ethnical and cultural issues that arise from the sequencing of the human genome. He specialises in Family Law, medico-legal law, and where the law interacts with the scientific world, and has published extensively in all these areas.

editing technology and its ability to manipulate genetic material using *in-vivo* and *ex-vivo* techniques, the scientific definition of genetic modification is evolving and thus the legislative definition, relying on *in-vitro* manipulation along with exceptions in regulations, requires review. Currently in New Zealand the use of gene editing technologies, including CRISPR-Cas, is likely deemed *genetic modification* and the organisms for which CRISPR-Cas is used, are deemed *new organisms* according to the HSNO Act. It is an offence to: develop or field test; or knowingly import or release, a new organism without prior regulatory approval (HSNO Act, section 109).

The HSNO Act and its regulating authority, the Environmental Protection Authority (EPA), have undergone judicial analysis. Most notable was *The Sustainability Council of New Zealand Trust v The Environmental Protection Authority* (Scion case; wilding pine),[9] which resulted in limiting the discretionary power of the EPA to assess editing techniques, emphasizing the *precautionary approach* and clarifying the classification of gene edited organisms as *new organisms* for the purposes of the Act. Additionally, the New Zealand Environment Court in *Federated Farmers of New Zealand v Northland Regional Council* (Northland Regional Council case; crops) enabled Regional Councils to control the use of genetic modification, under the Resource Management Act 1991, through regional policy statements and plans.[10] These cases have wide-ranging implications for New Zealand and are not generally limited to genetically modified wilding pines and crops, and by analogy apply to other genetically modified plants and possibly animals.

Aotearoa is unique and the Treaty of Waitangi is part of our constitution.[11] The HSNO Act contains provisions designed to ensure Māori views are taken into account when decisions are made about genetically modified organisms (HSNO Act, sections 4, 6(d) and 8). However, the Waitangi Tribunal concluded in the 2011 WAI 262 Report '*that the law and policy in respect of genetically modified organisms does not sufficiently protect the interests of kaitiaki in mātauranga Māori* [i.e. custodians or guardians of the body of knowledge originating from Māori ancestors] *or in the genetic and biological resources of taonga species*'.[12] Better implementation of Treaty of Waitangi principles and protection of kaitiaki in mātauranga Māori interests are central to inclusive decision making about gene editing in Aotearoa. Valuing the Treaty of Waitangi in legislation ensures that Treaty of Waitangi principles will underpin and guide all policy and decision making.

Throughout the paper the authors conclusions are expressed as ***considerations***, for review by government, regulators, policy makers, stakeholders and the public. New Zealand's regulatory framework warrants review in light of advanced genetic technologies and evolving societal, cultural and ethical views. This paper provides an analysis of New Zealand's regulatory framework, primarily focussing on the HSNO Act and other statutes as they apply to gene editing technologies (in particular CRISPR-Cas9) in pest control and primary industries.

While emphasis has been on the science and technical aspects of the law, Treaty of Waitangi principles should be the *overriding consideration* in a quest for policies that generate ora – intergenerational wellbeing for all of Aotearoa.

The Royal Commission of Genetic Modification recommended, in 2001 '*New Zealand should preserve its opportunities by allowing the development of genetic modification whilst minimising and managing the risks involved*'.[13] This is the underlying principle of this paper.

Regulation of the use of gene editing and gene drives for pest control

Next generation and novel pest control tools are being considered for use in New Zealand.[14] Gene drives using advanced gene editing technology have been investigated as a potential tool to assist the government in achieving New Zealand Predator Free status by 2050.[15]

Gene-editing tools have not been used to date in conservation of wildlife, but their use in the control of non-native invasive organisms is being explored with the use of gene drives.

In 2015, researchers demonstrated the use of CRISPR-Cas9 to develop 'gene drives', a genetic system named for the ability to 'drive' itself and nearby genes through populations of organisms over many generations. In normal sexual reproduction, offspring inherit two versions of every gene, one from each parent. Each parent carries two versions of the gene, having a 50% chance that a particular variant of the gene will be passed on. However, gene drives ensure that the genetic modification will almost always be passed on, allowing that variant to spread rapidly through a population. Dearden and co-authors offer a list of potential target species in New Zealand for genetic modification with technologies developed and required to implement a gene drive system.

[9] *The Sustainability Council of New Zealand Trust v The Environmental Protection Authority* [2014] NZHC 1067, (2014) 18 ELRNZ 331. The EPA has the power, upon receipt of an application, to determine whether an organism is a new organism for the purposes of the HSNO Act. In October 2012, Scion, the Crown Research Institute for forest resources, applied to the EPA for a determination of whether forest plants created by using Zinc-Finger Nuclease Type 1 (ZFN-1) and Transcription Activator-Like Effectors (TALENs) techniques were new organisms. In its application, Scion argued that ZFN-1 and TALENs techniques were equivalent to genetic changes made in plants through chemical mutagenesis and therefore were within the EPA's exemptions. EPA staff concluded that plants created with ZFN-1 and TALENs would be considered genetically modified organisms. But the EPA Committee decided that these plants would be exempt under the Regulations because ZFN-1 and TALENs techniques are more similar to chemical mutagenesis than genetic modification. The High Court Judge ruled that the exemption list is a closed list. The conclusion was based on an interpretation of the language of the Regulation and that the regulations did not prescribe factors for the EPA to add other techniques to the list. The Judge interpreted the HSNO Act and the regulations as not implicitly giving the EPA discretionary power to add to the exemption list and ruled that the EPA could not expand the exemption list to include techniques similar to chemical mutagenesis and adding to the exemption list was a political decision, not an administrative decision.

[10] *Federated Farmers of New Zealand v Northland Regional Council* [2015] NZEnvC 89, [2015] NZRMA 217 at [47].

[11] Harris BV. 2005. *The Treaty of Waitangi and the Constitutional Future of New Zealand*. NZ Law Review 189.

[12] Waitangi Tribunal Ko Aotearoa Tenei: A Report into the Claims Concerning New Zealand Law and Policy Affecting Maori Culture and Identity (Wai 262, 2011).

[13] Royal Commission on Genetic Modification. 2001. Ministry for the Environment. www.mfe.govt.nz/sites/default/files/media/Hazards/Royal%20Commission%20on%20GM%20in%20NZ-Final.pdf

[14] Dearden PK *et al.* 2018. The potential for the use of gene drives for pest control in New Zealand: a perspective. *Journal of the Royal Society of New Zealand*. p 1–20.

[15] Predator Free 2050. Department of Conservation <www.doc.govt.nz/predator-free-2050>

Potential target species include vespine wasps, pasture damaging weevils, Australian blowfly, possum, stoat, rats and mice.[16]

Gene editing a pest to include a gene drive would be regulated primarily by the HSNO Act. However, many statutes require referral, providing a complex regulatory framework for evaluating advanced genetic technologies as a method for controlling, managing and eradicating pests. It is seldom that one path would be taken. For example, administering a gene drive to rid New Zealand's conservation estate of possums will likely require at a minimum: animal ethics approval (Animal Welfare Act), a Pest Management Plan (RMA and Biosecurity Act), a conservation management plan (Conservation Act 1987), risk assessment for the agricultural industry and trade (Agricultural Compounds and Veterinary Medicines Act 1977), wild animal controls (Wild Animal Control Act 1977), along with approval from the Director General of Conservation (Conservation Act 1987), in addition to EPA approval for the new organism (HSNO Act 1996, section 27).

Gene drives are a disruptive technology, having the potential to lead transformational change in conservation, agriculture and in areas that we have not yet considered. It is recommended that regulation of gene drives in all contexts is required, as they risk reducing population genetic diversity along with potential development of resistant populations or strains.[17] For production animals and plants, these effects render the affected population more susceptible to management, disease and environmental challenge in the future.

No one organism should be evaluated in isolation of its ecosystem. A risk assessment method incorporating a long-term time-scale view, over a number of breeding cycles, is required to: reduce resistance to gene drives in pests and unwanted organisms; assess the impact on an ecosystem over time; investigate unintended consequences; and for production animals and plants (non pests) retain genetic diversity, essential for adaptation to changing environmental and management conditions.

(1) ***Consideration****: Risk assessment undertaken by the EPA balances beneficial effects against adverse effects (HSNO Act, section 38). Adverse effects will still be realised. An environmental bottom-lines approach is more supportive of the precautionary approach and should be deployed for disruptive technologies.*

(2) ***Consideration****: Regulatory complexity limits our ability to provide a coordinated and timely response. Regulation of gene editing technologies and their products comprises multiple pieces of legislation with different regulatory authorities. Biotechnologies (including gene editing technologies) would benefit from a single statute and a single entry-point for applications.*

Proposed use of CRISPR-Cas

The purpose for which CRISPR-Cas and other advanced genetic technologies are proposed to be used will direct the regulation pathway. Pest management is legislated under the Biosecurity Act 1993, where pest and unwanted organism are defined. Pest is also defined in the Agricultural Compounds and Veterinary Medicines Act 1997 in relation to agricultural security, where agricultural security is defined as the exclusion, eradication and effective management of pests or unwanted organisms under the Biosecurity Act (section 2(1)).

(3) ***Consideration****: Regulatory definition of 'pests' and 'unwanted organism' differs between multiple statutes. Legislative overlap for pests and unwanted organisms leads to regulatory complexity causing confusion for policy makers. Differing definitions in legislation and science will cause confusion for everyone. The following terms need to be defined consistently across legislation: animal, pest, unwanted organism, management of animals, biological product/compound and genetic modification.*[18]

[16] Dearden PK *et al.* 2018. The potential for the use of gene drives for pest control in New Zealand: a perspective. *Journal of the Royal Society of New Zealand.* p 1–20.

[17] *Ibid.*

[18] *Animal* is defined differently in both the Animal Welfare and ACVM Acts. *Pest* is defined differently in the Animal Welfare, Biosecurity and ACVM Acts. *Organism* and *unwanted organism* have the same meaning in both the Biosecurity and HSNO Acts. Animal Welfare Act refers to *biological product*. Does this have the same meaning as *biological compound* in the Agricultural Chemicals and Veterinary Medicines Act? Animal Welfare Act includes *genetic modification* of breeding animals, but does not define *genetic modification* and does not refer to the HSNO Act for definition. *Management* of animals is not defined in legislation and therefore could be interpreted to mean the control and eradication of agricultural pests.

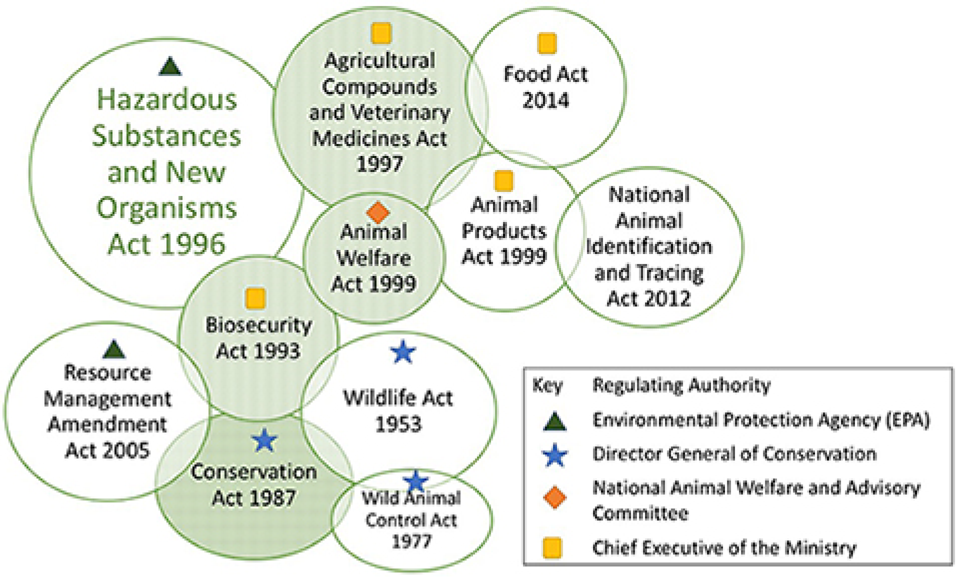


Figure 1. New Zealand legislation influencing genome editing technologies in animals and other organisms. The Hazardous Substances and New Organisms Act 1996 is the primary statute. Overlapping statutes have interacting provisions. Please note that the Animal Welfare Act and the HSNO Act are not joining, as the Animal Welfare Act's ***genetic modification*** term does not refer to the HSNO Act for meaning. Regulating authorities for each of the statutes, are presented in the key provided.

(4) ***Consideration****: Once genetically modified, and deemed a new organism, is the new organism still deemed a pest or unwanted organism? For example, wilding pine species, lodgepole pine (Pinus contorta) are deemed unwanted organisms according to the MPI unwanted organism database (UOR).*[19] *Would a genetically modified wilding pine species rendering it sterile and thus a new organism still be deemed a pest or unwanted organism? Reclassification of new organisms will be required, as they may no longer be deemed unwanted organisms or pests.*

(5) ***Consideration****: Should EPA's assessment of risk differ for applications to genetically modify and release unwanted organisms and/or pests from that for non-pests? These organisms are already causing harm to the environment in their natural, non-genetically modified and wild type state. Review risk assessment provisions in the HSNO Act for genetically modifying pest and unwanted organisms.*

Regulation of gene editing in primary production

Gene editing for primary production such as reducing environmental impact of wilding pines, responding to insect pests, speeding up apple breeding, protecting taonga species such as mānuka and providing new human health benefits from cow milk requires evaluation of a vast network of regulatory instruments alongside the HSNO Act.[20] Primarily, the Agricultural Compounds and Veterinary Medicines Act 1997 (ACVM Act); Animal Welfare Act 1999; Biosecurity Act 1993; Resource Management Act 1991; and the Cartagena Protocol to the Convention on Biological Diversity, require referral.

(6) ***Consideration****: Regulatory complexity. Primary industries regulation of gene editing technologies and their products comprises multiple pieces of legislation with different regulatory authorities. Biotechnologies (including gene editing technologies) would benefit from a single statute and a single entry-point for application. (Refer to Figure 1, Consideration 2).*

Gene edited plants and animals pose significant new challenges for regulation. Under current legislation (HSNO Act) and a judicial ruling in *The Sustainability Council of New Zealand Trust v The Environmental Protection Authority* [2014] NZHC 1067 (Scion case)[21] on interpretation of that legislation, gene-edited crops and animals are deemed genetically modified. However, in many cases gene edited crops and animals will have genetic modifications that in theory could be induced by non-regulated methods, such as radiation or chemical-induced mutagenesis prior to 1998, or simply occurring naturally from spontaneous mutation (HSNO Act 1996; SR 1998/219, r 3(ba)). This calls into question the robustness of a risk management approach that focuses on how the modification is produced rather than the risks posed by the organism/product developed.

For importers, in the absence of a declaration process, it will be difficult to distinguish gene-edited organisms and products from non-modified contemporaries. The export of living modified organisms is prohibited, except as provided by the Imports and Exports (Living Modified Organisms) Prohibition Order 2005. Exporters require authorisation from the Minister for the Environment to export living modified organisms (LMO's) intended for: contained use (clause 6); food or feed or for pro-

[19] MPI Unwanted Organisms Database < www.mpi.govt.nz/protection-and-response/long-term-pest-management/handling-unwanted-organisms/>

[20] Gene editing in the primary industries. 2018. Royal Society Te Aparangi Gene Editing Panel <www.royalsociety.org.nz/major-issues-and-projects/gene-editing-in-aotearoa/>

[21] *The Sustainability Council of New Zealand Trust v The Environmental Protection Authority* [2014] NZHC 1067, (2014) 18 ELRNZ 331.

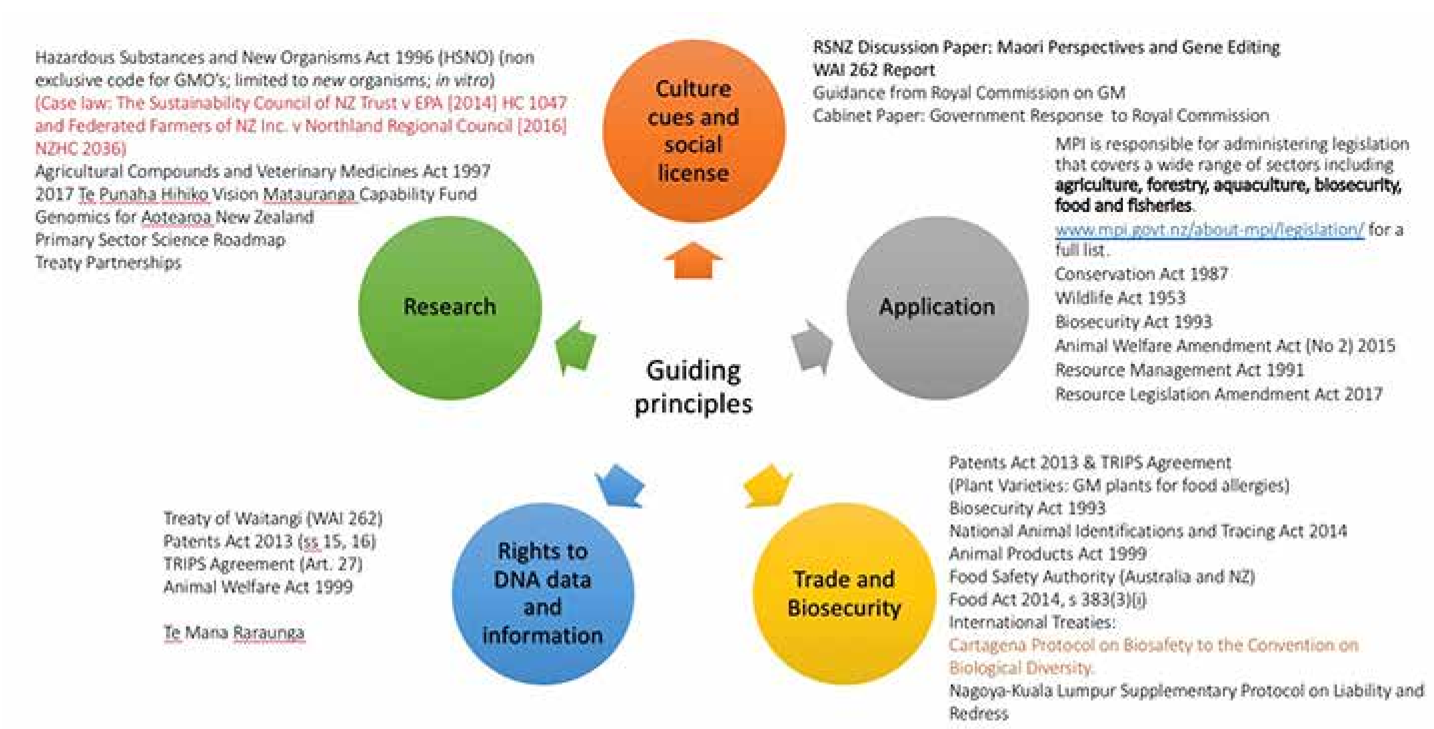


Figure 2. Gene editing regulation in New Zealand's primary industries.

cessing (clause 7); intentional introduction into the environment (clause 8), according to the Cartagena Protocol.[22]

*(7) **Consideration**: Regulatory oversight - challenge of recognising imported gene edited products, with international agreements on what is being regulated varying between countries. The definition of genetic modification differs between countries and jurisdictions. Gene editing cannot be detected in some situations. A review of international regulation is required along with an assessment of the implications for New Zealand's international trade agreements.*

Agricultural Compounds and Veterinary Medicines Act 1997 (ACVM Act)

In addition to the HSNO and Biosecurity Acts, the ACVM Act has possibly the greatest effect on this technology. The purpose of the ACVM Act is to prevent or manage the risks associated with *agricultural compounds* (ACVM Act, section 2(1)),[23] ensure the use of *agricultural compounds* does not breach domestic food residue standards and consumers receive sufficient information about agricultural compounds (ACVM Act, section 4). The ACVM Act aims to achieve its purpose by providing that no *agricultural compound* may be used, including imported, manufactured or sold in New Zealand unless its use is authorised under the Act (ACVM Act, section 4A(1)).

Gene editing use in New Zealand's primary industries can meet the definition of a *biological compound* and subsequently an *agricultural compound* for managing plants and animals (ACVM Act, section 2(1)). The purpose of the Act is to prevent and manage risks associated with agricultural compounds to: public health; trade in primary produce; animal welfare and agricultural security (ACVM Act, section 4).

[22] The Cartagena Protocol to the Convention on Biological Diversity, in accordance with the precautionary approach contained in Principle 15 of the Rio Declaration on Environment and Development, is an international agreement that aims to ensure an adequate level of protection in the field of safe transfer handling and use of *living modified organisms* (LMOs). Particular attention is given to LMO resulting from biotechnology that may have adverse effects on the conservation and sustainable use of biological diversity, considering risks to human health and specifically focusing on transboundary movements (Article 1).

[23] The ACVM Act section 2(1) defines agricultural compound as—

(a) any substance, mixture of substances, or biological compound, used or intended for use in the direct management of plants and animals, or to be applied to the land, place, or water on or in which the plants and animals are managed, for the purposes of—

- (i) managing or eradicating pests, including vertebrate pests; or
- (ii) maintaining, promoting, or regulating plant or animal productivity and performance or reproduction; or
- (iii) fulfilling nutritional requirements; or
- (iv) the manipulation, capture, or immobilisation of animals; or
- (v) diagnosing the condition of animals; or
- (vi) preventing or treating conditions of animals; or
- (vii) enhancing the effectiveness of an agricultural compound used for the treatment of plants and animals; or
- (viii) marking animals; and

(b) includes—

- (i) any veterinary medicine, substance, mixture of substances, or biological compound used for post-harvest treatment of raw primary produce; and
- (ii) anything used or intended to be used as feed for animals; and
- (iii) any substance, mixture of substances, or biological compound declared to be an agricultural compound for the purposes of this Act by Order in Council made under subsection (2).

Gene edited products used to *manage* animals will undergo risk assessment according to the ACVM Act. A *veterinary medicine*, according to the ACVM Act (section 2(1)), means any substance, mixture of substances, or *biological compound* used or intended for use in the *direct management* of an animal. A *qualifying veterinary medicine* is defined in the HSNO Act (section 2(1)) as a *veterinary medicine* that is or contains a *new organism*; and meets the criteria set out in section 38I(3) of the HSNO Act.

*(8) **Consideration**: There is potential for imported gene-edited animals and plants (and other organisms) to bypass containment provisions in the HSNO Act and to be released without controls (HSNO Act, s 38I(1)). This is legally possible when advanced genetic technology is deemed a 'qualifying organism' in a 'veterinary medicine' used in the 'direct management of the animal'. This consideration would also apply to the management of pests. An assessment of potential implications is required should containment be bypassed, for a qualifying organism in a veterinary medicine. Should legislation be amended to ensure imported veterinary medicines are imported into containment?*

Animal Welfare Act 1999

The Animal Welfare Act determines whether animals can be manipulated (Animal Welfare Act 1999, section 3). The CRISPR-Cas genetic technique and the reproductive technique used to genetically modify animals is deemed a *manipulation* (Animal Welfare Act 1999, section 3(1)(a)(i) and section 3(1B)). Manipulation includes the breeding or production of an animal using any breeding technique (including *genetic modification*) that may result in the birth or production of an animal that is more susceptible to, or at greater risk of pain or distress during its life as a result of breeding or production (section 3(1B)). This provision considers the effect of *genetic modification* on the animal's production performance and on its progeny.

*(9) **Consideration**: The associated effect of an edited gene on other genes in the animal may not be known and is required to determine the risk of adverse effects on resulting progeny under the Animal Welfare Act 1999 (section 3(1B)). Ensure animal genetic association analyses and findings are incorporated in risk assessment methods.*

*(10) **Consideration**: Regulatory definition - genetic modification is not defined in the Animal Welfare Act and this Act does not refer to the HSNO Act for interpretation. Amend the Animal Welfare Act to refer to the HSNO Act for definition of genetic modification.*

Manipulation of an animal means to deliberately interfere with the normal physiological, behavioural, or anatomical integrity of the animal by deliberately subjecting it to a procedure which is unusual or abnormal when compared with that to which animals of that type would be subjected under *normal management or practice* (section 3(1)(a)). The procedure involves exposing the animal to any *microorganism or biological product* (section 3(1)(a)(ii)).

*(11) **Consideration**: Lack of regulatory definitions and inconsistent regulatory definitions leads to stakeholder uncertainty for proposed use of advanced genetic technol-*

ogies. The following terms are not defined by the Animal Welfare Act 1999 and do not refer to other legislation for definition: normal management or practice, biological product and microorganism. Amend the Animal Welfare Act to include definition for these terms.

Summary

At the International Summit of Gene Editing in 2015, Alta Charo reported that '*the regulatory framework is going to determine the speed at which biotechnology moves from laboratory to research to marketed product*'.[24]

Existing regulation for a platform technology, such as advanced gene editing, with broad use is complex. Immediately, consistent interpretation of terms between statutes and international agreements is required as *statutory borrowing* of terms is rarely used.[25] The Scion Case has emphasized the importance of correctly interpreting *new organism* and *genetic modification*, concluding that the relevant Regulation (SR 1998/219, r 3) provides an exhaustive list that can only be modified by Parliament.[26] This decision has implications for CRISPR-Cas technologies, potentially classifying all organisms for which CRISPR-Cas is used as genetically modified when the nucleotide alteration may be no different than mutagenesis or a modification to wild type.

In summary, regulation of gene editing technologies has come to a crossroads and provides an opportunity to review current regulatory frameworks and devise a future-proof framework to keep abreast of rapidly advancing biotechnologies.[27]

In brief, this paper's authors purport New Zealand would benefit from an integrated regulatory system for biotechnologies:

a. Led by Treaty of Waitangi principles;[28]
b. Governed by shared values for Aotearoa New Zealand, such as: uniqueness of Aotearoa; our indigenous and cultural heritage; sustainability; being part of a global family; well-being of all; freedom of choice and participation (as recommended by the Royal Commission on Genetic Modification);
c. Having a single entry-point for applications, to promote efficiency and minimise costs for researchers and stakeholders;
d. Regulated by one Authority (for conservation, biosecurity, primary industries and human health), with capability to horizon scan;
e. Incorporating WAI 262 recommendations, to enhance the statutory power of Maori;
f. Incorporating sub-tiers of multidisciplinary expertise in conservation, biosecurity, primary industries and human health; containing scientific, advisory and ethics committees which strive to keep abreast of global biotechnology developments and aim to preserve opportunities for Aotearoa;
g. Regularly reviewed and consistent interpretation of key statutory terms;
h. That uses systems-based risk analysis processes, incorporating an environmental bottom-lines approach for disruptive technologies such as gene drives;
i. That compares the new biotechnology against alternative tools and technologies; and
j. That utilises modelling to assist the prediction of future genetic diversity and resistance in populations.

This paper has identified some of the complexities of the legislation inherent in regulating a rapidly developing technology where such advances may be well ahead of current frameworks and public acceptance. A resilient legislative and regulatory approach is required whereby new legislation for biotechnologies is developed and a single entry-point for biotechnology applications is implemented.

[24] Charo A. 2015. International Summit on Human Gene Editing: A Global Discussion. In: Olson S. (ed.) 2015. *International Summit on Human Gene Editing: A Global Discussion*. Washington (DC).

[25] Burrows and Carter Statute Law in New Zealand, 5th Edition. 2015. Statutory borrowing of definitions: Except in cases where one statute expressly adopts the definition of another, statutory burrowing seldom occurs as each statute is a separate entity and the meaning of the words in that statute do not depend on other statutes. There have been occasional instances of judicial borrowing of definitions in New Zealand. This practice may be adopted where two statutes are in *pari materia* (on the same subject), but this cannot be relied upon. Relevant case law suggests a number of factors when definitions may be borrowed and include: the statutes having a similar purpose, administered by the same officers and passed into law about the same time. A comparison of the purpose and context of the Acts is critical. Borrowing of definitions is only to take place with great caution.

[26] *The Sustainability Council of New Zealand Trust v The Environmental Protection Authority* [2014] NZHC 1067, (2014) 18 ELRNZ 331.

[27] Marchant GE, Stevens YA. 2015. A new window of opportunity to reject process based biotechnology regulation. *GM Crops and Food*. 6: 233–242.

[28] The principles of the Treaty of Waitangi were discussed in *New Zealand Maori Council v Attorney General* [1987] 1 NZLR 641 (CA). The Court found that the agreement between Maori and the Crown gave rise to a *partnership*, to act in *good faith, fairly and reasonably*. The Crown's duty extended to active protection of Maori in the use of their lands and other interests to the fullest extent practicable.

Some unremembered chemists:

Francis Brian Shorland, OBE, PhD, DSc (L'pool), Hon. DSc(VUW), FRSNZ (1909-1999)*

B Halton†

Francis Brian Shorland (known as Brian) was born on 14 July 1909 in Island Bay, Wellington, New Zealand. His father John Olive Shorland (1864–1946) had been a long-distance cycling racer in the South Island and subsequently owned and operated a cycle shop in Cuba Street in Wellington.[1] However, John's career was as diverse as it was engaging. It encompassed building, architecture, furniture and three years as a City Councillor (1917–1920). His wife, Edith Sophia Perry, was a school teacher from the South Island West Coast and they met while she was a student at Canterbury University College. They were married in 1898 and had four children, of whom three survived to adulthood, Brian being the youngest.

Dr Francis Brian Shorland (from *Brian Shorland – Doyen of New Zealand Science*, p. iii; courtesy of the New Zealand Association of Scientists)

Brian's education began in the Miss Hills' Kindergarten in Island Bay, where he stayed for two years before moving to Island Bay School at six years of age. There he had the usual rudimentary primary education prior to entering Form 3D at Wellington College in 1920. It was the lowest available, as he was not a gifted student. For him, college education lacked a good grounding in everything but Latin, at which he excelled, and he only just managed to pass the state examinations in English and Physics (Chemistry was not taught at that time). Despite this, his school teacher-trained mother and sister had him back to the college for an extra year in Form 6B, and at the end of that 1926 year he gained a partial pass in the Matriculation exams. He stayed on, gaining another partial pass the following year, and full Matriculation was awarded in January 1928 with Engineering and Solicitor's general knowledge. Having missed out on a job in a Christchurch wireless shop that would have let him attend Canterbury University College, and on the advice of his sister Jessie, he was engaged in the Agriculture Department Accounts Office in 1927. After a few months, a vacancy became available in the Agriculture Department Laboratory, and Brian was transferred there as a cadet (trainee scientist).

At that time Victoria University College (VUC) had moved to daytime lectures and the Agriculture Department and the newly established Department of Scientific and Industrial Research (DSIR) allowed their cadets to spend up to seven hours per week for tertiary study. Brian enrolled at Victoria, registering for Physics 1 and Pure Mathematics 1, and subsequently moved to chemistry and zoology in his second year, graduating with a BSc in chemistry in June 1931. He was able to take six months leave of absence and, with a Jacob Joseph Scholarship, he undertook an MSc the following year. He graduated with 1st Class Honours in chemistry from work studying the reactions of glycols and dibasic acids. His thesis was entitled: 'The rate of esterification of isoamyl alcohol and glycol by dibasic acids',[2,3] and was subsequently published in the *Journal of the American Chemical Society* in 1935.[4]

Professor Robertson (see: Chemistry in New Zealand, 2015, 79: 51–55) was the sole organic chemist at that time and the thesis followed tradition by neither naming nor acknowledging him as supervisor.

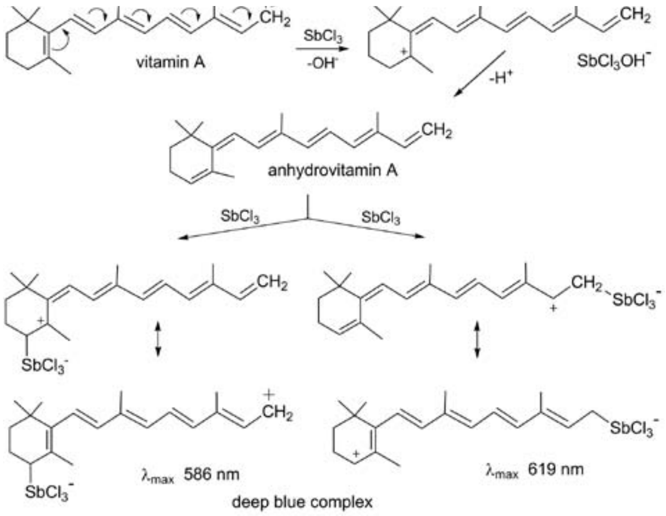
The MSc studies did not provide Shorland with his first publication. His work at the Agricultural Laboratory as a cadet was to assist staff in their projects under Bernard Aston as chief chemist. One of those there was Dr J.A. Bruce. At that time Bruce felt that New Zealand geothermal resources could be utilised, and especially steam, in energy production. Young Shorland became interested and collected samples from Wairakei for analysis and the results gave him his first two publications.[5] However, the managers of the time had little or no interest, and the work lay dormant until the late 1940s, when the science was advanced and a pilot plant subsequently constructed, producing 20 MW power by late 1952.

Following contributions to a range of projects, Shorland and his cadet colleague Frank Denz were asked to test dried and processed eel from a farm on the basis that it might provide food for pigs. The tests with the oils product proved difficult and it was suggested that the project be abandoned. However, having

*First published in *Chemistry in New Zealand* (2018) vol. 82(3): 139–144, and reproduced here with permission, this is one of a series of articles that explores the lives and work of selected chemists who have made a significant contribution to the advancement of the discipline, the profession, and the well-being of mankind, yet who are little remembered.

†Deceased 23 February 2019. Professor Brian Halton studied chemistry at the University of Southampton, graduating BSc(Hons) in 1963 followed by a PhD in 1966. Moving to New Zealand in 1968, he was appointed to the Department of Chemistry at Victoria University of Wellington, eventually becoming professor there. When he retired in 2004, he was conferred the title of professor emeritus. His research was centred on the synthesis and investigation of highly strained and fused aromatic compounds. The New Zealand Association of Scientists awarded him its Research Medal in 1974, and the Shorland Medal in 2001. He was active in the New Zealand Institute of Chemistry and was elected a Fellow in 1977, and most recently was advisory editor for its journal, *Chemistry in New Zealand*. He became a Fellow of the Royal Society of New Zealand in 1992. In his retirement, he pursued his interest in the history of chemistry, writing a history of the chemistry department at Victoria University, and co-editing with his colleague, Professor Emeritus Neil Curtis, a biography of Brian Shorland written by Dr Joan Cameron and published by NZAS.

assisted in setting up the equipment for the Carr-Price test[6] for vitamin A (something new to the department at that time), the two cadets tested the eel meal for the vitamin. It involved preparing a standard solution of 30% antimony trichloride ($SbCl_3$) and adding it to the vitamin A in chloroform to give a complex whose deep blue colour was measured colorimetrically (Scheme 1). Their success led them to examine the livers of fish caught off the Wellington coast, and the results of their unofficial project was the beginning of Brian Shorland's lifelong adventures into fats and lipid chemistry, and the first paper he wrote.[7]



Scheme 1. The chemistry of the Carr-Price test

Following his MSc degree, Brian continued with studies at VUC, taking and passing Philosophy III, Statistical Methods, and Economics, and became a classified scientist in the Agriculture Department working on his own projects. His first two years led to 12 publications on diverse topics that included geothermal heat utilisation, pampas grass as a supplement for cattle, aluminium as a causative agent in pasture bush sickness, and fish oils, one jointly with Aston. Yet the young man, now in his mid-20s wanted to progress his education to the PhD level and advance his interest in fish oils, something not then possible in New Zealand. With this intention, he applied to the Liverpool School of Fats Research to carry out PhD studies with Thomas P. Hilditch, the inaugural professor of industrial chemistry. His application was successful and he was granted leave from the Agricultural Lab with a Council of Scientific and Industrial Research National Research Scholarship. Although he was by this time engaged to Betty Purvis of Wellington, he left for London, boarding the 12 passenger-carrying ship, the twin-screw motor vessel (TSMV) *Port Fairy* in September 1935, arriving in London some 35 days later. His arrival in industrial northwest England and Liverpool was by train, and the city was something he had never seen the likes of before. Settling was far from easy, though he had accommodation with a sensible family.

The work Brian undertook for his doctoral degree was the study of fats from farm animals and fish liver oils, which he had brought with him from New Zealand with Hilditch's approval. At that time Hilditch ran the foremost group studying fats, waxes and oils, and was writing his major work *The Chemical Constitution of Natural Fats* published in five editions from 1940. The group's approach to characterising lipids was to hydrolyse them to their fatty acid components, esterify these (methanol) and separate the esters by fractional distillation. A lipid is a substance of biological origin that is soluble in nonpolar solvents. It comprises a group of naturally occurring molecules that include fats, waxes, sterols, fat-soluble vitamins, e.g. A, D, E, and K, mono-, di- and triglycerides, phospholipids, and others. The glycerides are the mono- di- or triesters formed from glycerol (1,2,3-trihydroxy-propane), and animal and fish fats are triglycerides.

The phospholipids have one carboxylic ester function replaced by a hydrophilic phosphate ester (Charts 1 and 2 and below). Chromatography was still little known; the Russian-Italian botanist Mikhail Tsvet had developed paper chromatography early in the 20th century, but it was not until the pioneering work of Martin[8] and Synge[9] in the early 1940s that partition chromatography became popular. In that era the constitution of fats and oils was determined using the saponification number and iodine value. The saponification number represents the number of milligrams of KOH required to hydrolyse (saponify) one gram of fat under specified conditions. It is a measure of the average molecular weight of all the fatty acids present. The long-chain fatty acids (see, e.g. Chart 2) present in fats have

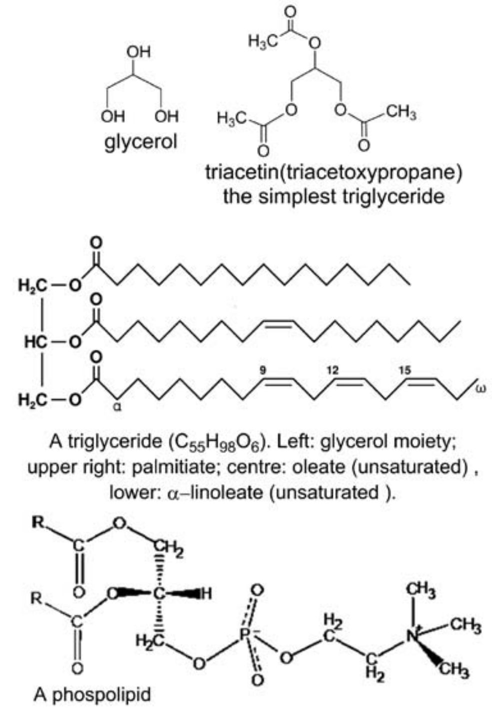


Chart 1. Glycerol, and examples of triglycerides and a phospholipid

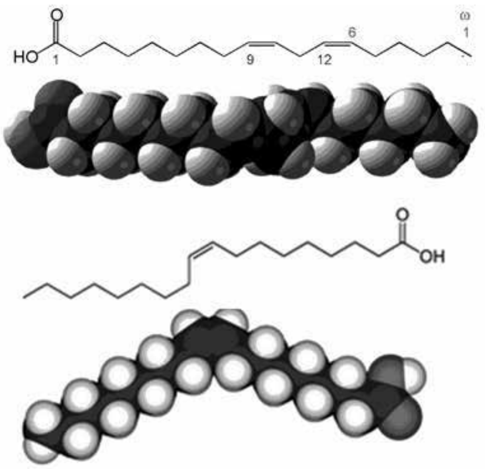
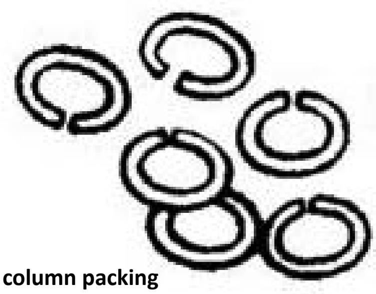


Chart 2. Upper:*cic,cis*-linoleic ($C_{18}H_{32}O_2$), and lower: *cis*-oleic acid ($C_{18}H_{34}O_2$) formulaic and as space filling models

a low saponification value because they have relatively fewer carboxylic acid groups per unit mass of the fat as compared with short-chain fatty acids. If more moles of base are required to saponify N grams of fat, then there are more moles of the fat and the chain lengths are relatively small. The iodine value is the mass of iodine in grams that is consumed by 100 grams of the unsaturated compound and provides a measure of the unsaturation in fatty acids. The higher the iodine number, the greater the number of C=C double bonds present in the fat.

These tests were pivotal to Brian Shorland's doctoral studies[10] as illustrated in his 1937 and 1938 papers with Hilditch.[11,12] Moreover, Brian and an Indian doctoral candidate named Minocher Bomonji Ichaporia[13] spent Saturdays in the Hilditch lab achieving more than the local students who were at sporting events. Frenske spiral packing in columns, introduced to Liverpool by American postdoctoral fellow Herbert Longeneker, was particularly effective and the two graduate students discovered that the longer the column the more efficient the separation.

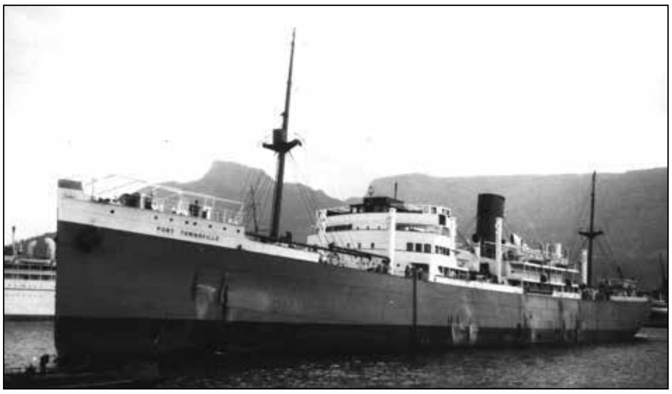


Fenske spiral column packing

Between 1934 and 1938 Brian's father, by then retired, prepared and exported as much as 144 gallons of fish-liver oil annually from Island Bay to British Drug House Ltd in London. With the contacts that this established, Brian was able to spend his vacations in the company laboratories and use one of the first spectrophotometers to aid in determining the vitamin A content of the oils from New Zealand.[14]

Brian's 1937 doctoral thesis was in essence in two parts, both of which involved triglycerides. That which formed his first paper[11] with Hilditch was a determination and comparison of the composition of the component fatty acids present as glycerides and phospholipids (Chart 1; phospholipids are major components of cell membranes) in the livers of ox, cow, pig, and sheep. The second was more closely related to Brian's prime interest, namely a study of aquatic (fish) fats[12] and gave a further four papers from Brian and his New Zealand collaborators.[15] At that time all such studies had involved species inhabiting the Northern Hemisphere and it was of particular interest to examine the fish oils of New Zealand species because many were (and are) peculiar to the Southern Hemisphere. The oils selected were from the livers of red cod, 'English' hake, and groper, as well as the head oil from this last species. The groper showed a marked seasonal variation from spring through winter in its vitamin A, iodine value, and non-hydrolysable matter content.

The external PhD examiner was Professor J.C. Drummond (later Sir Jack), the inaugural Professor of Biochemistry at University College London. His report was favourable and, with his PhD, Brian returned to New Zealand on the refrigerated cargo ship, the MV *Port Townsville*, which left London's Tilbury Docks on 12 October and called at a number of ports including ones in Australia before arriving in New Zealand in the spring of 1937.



The MV *Port Townsville* (from The AllenCollecton – Port Line, courtesy B. Watson; see http://www.benjidog.co.uk/allen/Port%20Line.html)

On return to the Agricultural Chemistry laboratory in Wellington, Brian Shorland was faced with change. Aston had retired, and the deputy since 1927, R.E.R. (Dick) Grimmett, who had tutored Brian in his cadetship, was Director.

With his doctoral degree in hand, Shorland was appointed as Chemical Advisor – Grimmett held his qualifications in zoology – and was largely able to choose his own research topics. He became recognised for expanding his horizons, not just scientifically at the bench but in terms of the space he and his projects occupied,[1] a trait that continued even into his later life and office in Victoria University's Biochemistry Department (see below).

His studies continued the interest in fish and eel oils with his Director's support. The work turned to exploring the eel oil content during maturation and an examination of both types of New Zealand eel, the log-finned *Anguilla aucklandii* and the short-finned *Anguilla australis* at various stages of their life cycle. The former matures at about 20 years of age and 5 kg in weight, while the latter does so at 5 years old and 1 kg; significant results followed. Study also included the body fat composition of farm animals, especially pigs and then sheep. These studies were extensively published and provided proof that fat was incorporated from diet, and that this fat was deposited uniformly in the storage fat of the animal. The composition of fatty acids did not change throughout the body; diet was then accepted as the important factor in determining the structure of body fat in an animal. This work led Brian to question the nature of diet and take him on to become a world recognised expert in the area. Between 1932 and 1949 Shorland had some 42 publication on the fats of fish and mammalia, and of grasses and other forage plants mainly of New Zealand origin.

In 1946, the Agriculture Department laboratories were moved from Wellington and amalgamated with the Ruakura Research Station near Hamilton, where Dr C.P. McMeekan, its first director, specialised in research to define the most productive management systems on dairy farms. The move was made for added focus on the facial eczema problem, but it did not include Brian Shorland. He transferred to the DSIR where he was appointed Director of a newly established Fats Research Laboratory.

It was established as a separate division of the DSIR to determine the fundamental nature of economically important fats, then a major source of New Zealand overseas income. At that time, more than one-third of the weight of everything New Zealand exported was fat, and the initial emphasis was on the vitamin A content of New Zealand butter, so as to comply with a short-lived British requirement.[3] The laboratory grew to a staff of 20, of whom half were chemists, and it soon became recognised as a leading centre for lipids research. Before the 1940s, lipids research was in its infancy to the extent that lipids were proffered as having no physiological purpose other than for energy storage. Fats were considered to comprise even-numbered straight carbon chains with no nutritional value save for the essential linoleic acid present (see Chart 1).

It was the work of the DSIR Fats laboratory and Brian Shorland that proved that fats were markedly more diverse than had been thought, with odd numbers of carbon atoms and branched chains common. Phospholipids (Chart 1) and galactolipids (Chart 3) were present in addition to the common glycerol-lipids. The essential feature of a glycolipid is the presence of a monosaccharide or oligosaccharide bound to a lipid moiety whereas the galactolipid has galactose as its carbohydrate moiety (Chart 3). Shorland's work at the Fats Research laboratory (the Food Chemistry Division from 1966) demonstrated the presence of fatty acids from C_4 to C_{26}, that common fats were much more diverse than previously thought and that they included branched chain and unsaturated examples that could be either of E or Z configuration. Their studies established that the depot fats of ruminants reflected their dietary intake modified by the ruminant organisms largely saturating the unsaturated fats, whereas those of non-ruminants were directly reflective of their diet. They showed that lipid structures have a variety of important physiological roles. They went on to show that theories held relating to carcass fat composition were incorrect and that the then-held evolutionary theory of animal fats was wrong and a new one was developed.

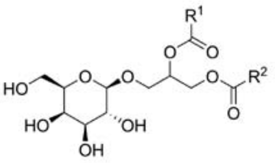
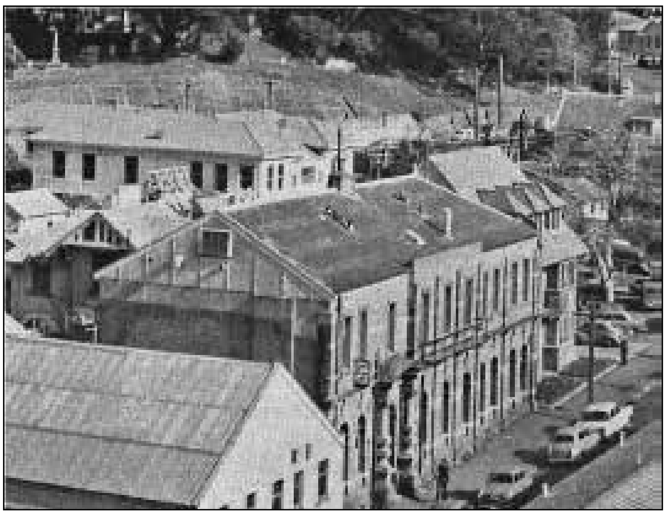


Chart 3. A monogalactosyl diacylglycerol - a galactolipid

As time and export markets evolved, Shorland and his team explored why the odour of mutton fat was unacceptable to the Japanese. In essence, the laboratory team made significant and important discoveries to the understanding of lipids, their nutritional value of particular importance to the New Zealand industries dependent on them. And Shorland's international reputation grew.



The DSIR Fats Research Laboratory, Sydney Street East, Wellington and original home of the New Zealand Dominion laboratory (from *Brian Shorland – Doyen of New Zealand Science*. p.87; courtesy of the New Zealand Association of Scientists).

When the United Nations General Assembly asked its protein Advisory Group to increase the production and use of edible protein,[16] Shorland devised high-protein food from wool, at which time the country had a vast excess.

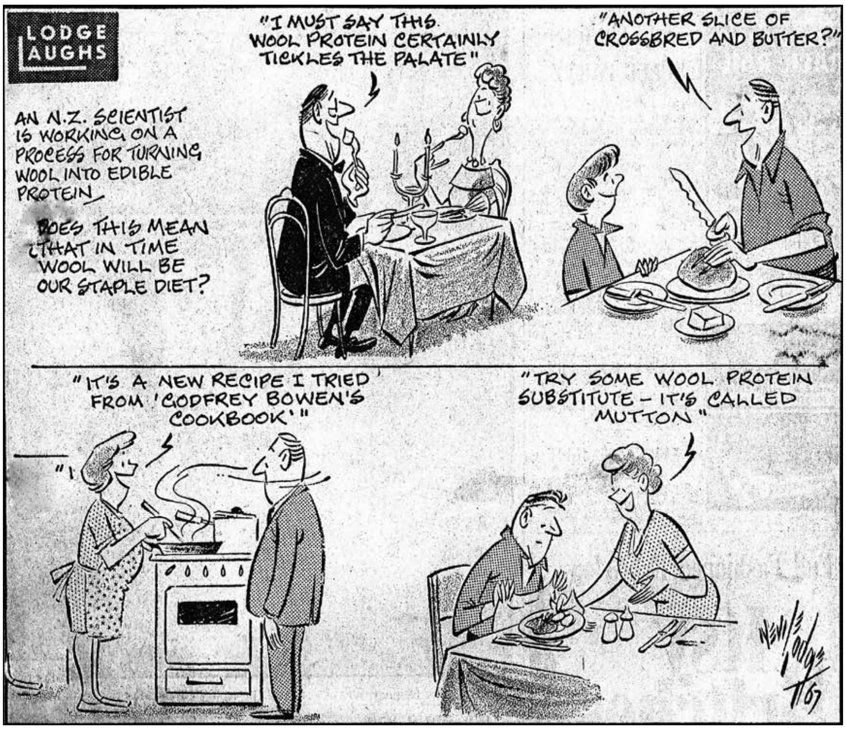
He subjected wool to a chemical and a biochemical treatment and in his 1969 paper,[17] he stated: 'Edible protein derived from wool is assessed with respect to its suitability for human food. Compared to the FAO (Food and Agriculture Organisation of the UN) reference pattern for human requirements of amino acids, wool protein is deficient mainly in methionine, and less so in lysine and tryptophan. … It is estimated that edible wool protein can be manufactured for <25 cents/lb'. The chemical process involved use of sodium sulfide-sodium sulfite followed by precipitation with acetic acid and the biochemical process[18] employed the kiwi fruit enzyme actinidin (a member of the papain family). Irrespective of the method, the amino acids solutions were dried to a white powder that lacked the essential dietary sulfur-containing acids, and so the most important of them, methionine, was added.

The successful outcome with laboratory rats led to human trials with the powder added to standard whole-meal breads, ginger nuts and sponge cakes; the products were fully edible. Up to 35% of baking flour could be replaced without affecting product acceptability. Shorland and his colleagues gained widespread publicity, as exemplified by the Lodge Cartoon in the Wellington evening paper (next page). What was perhaps more remarkable was that the processing could be applied to used and dyed woollen knitted clothing including socks!

His conversion of protein into food did not stop there. He published three papers on the equivalent production of food from feathers. Feathers contain 85–90% keratin that must be hydrolysed to make it digestible. In that process the disulfide and amide bonds in the keratin are broken to form more digestible smaller proteins, peptides and amino acids. Rendering the feathers was the traditional method of hydrolysis,[19] but it was Draper[20] who first tried treating feathers with sodium sulfide and sodium hydroxide. Interestingly, in 2012, biotechnologists at Lund University (Sweden) refined a micro-organism to convert chicken and turkey feathers into soluble protein.[21] Their spin-out company Bioextrax now provides 900 g of protein from 1 kg of feathers, and it has a patent pending for their conversion into animal feed.[22]

In Shorland's era, government service employees retired on pension at 60 years of age, and so, at the end of 1969, retirement was forced upon him. He was fortunate, however, in having professional colleagues at Victoria University and he was able to transfer and become an unpaid Honorary Lecturer in Biochemistry, a role he held until 1987, when he was redesignated an Honorary Research Fellow. He remained there, filling his office with papers and files, until his death in 1999.

The year 1971 had seen Brian appointed as convener of the Government-requested panel on coronary heart disease established by the Royal Society of New Zealand (RSNZ). The study took over a year, with a final report clearly suggesting that cholesterol and heart disease were not causally related. Replacing butter by margarine did little but aggravate the problem while increasing the intake of ω-3 fatty acids as in fish oil and olive oil



Neville Lodge cartoon, *The Evening Post*, Wellington, 11 December 1967 (from *Brian Shorland – Doyen of New Zealand Science*, p. 121; courtesy of the New Zealand Association of Scientists).

(which contains up to 1.5% of the ω-3 fatty acids linolenic acid) was beneficial. He continued with his dietary thrust, concluding in 1987 that the results of the various cholesterol-lowering regimes had been misinterpreted. More importantly, by then the biochemical understanding of the clotting mechanism was soundly based and could not support cholesterol as causative.[23]

As time passed, science in New Zealand came under government scrutiny, resulting in major reorganisation in the 1990s. Brian Shorland had joined the New Zealand Association of Scientific Workers in 1945 and remained involved with it through its morph into the Association of Scientists (NZAS) until his death. As a senior scientist he took it upon himself to be a critic of government, and he wrote and spoke widely on the topic of reorganisation. He served on the Association's Council from 1963 until the mid-1990s, was Vice-President 1965–1967, and President 1954–1955. He was Editor of the Association's Journal, *New Zealand Science Review* from 1985 until the mid-1990s. He was awarded his DSc by Liverpool in 1950, elected Fellow of the Royal Society of New Zealand in 1951, gained an OBE in 1959 and given an honorary DSc by Victoria University in 1970. He was awarded the NZAS premier award, the Marsden Medal, in 1970 and was Patron of the organisation from 1955 until his death in 1999. The Association established the Shorland Medal for lifetime contribution to scientific knowledge in his honour later that year.

Brian Shorland was married three times. His first wife, to whom he was engaged while in Liverpool and married on 27 January 1938 shortly after his return, was Betty Purvis. The couple had twins, John and Alison, in 1948 and the New Zealand Institute of Chemistry announced the event in the March 1948 issue of its Journal as: 'We congratulate Dr and Mrs F.B. Shorland of Wellington on the discovery of two new isomeric compounds, one trans and one cis'. The second marriage was for eight years and the third for some five years. Brian Shorland died in his sleep at his Karaka Bay Road home on 8 July 1999, some five days before his 90th birthday. His daughter continues to live in the old family home in Derwent Street, Island Bay, Wellington.

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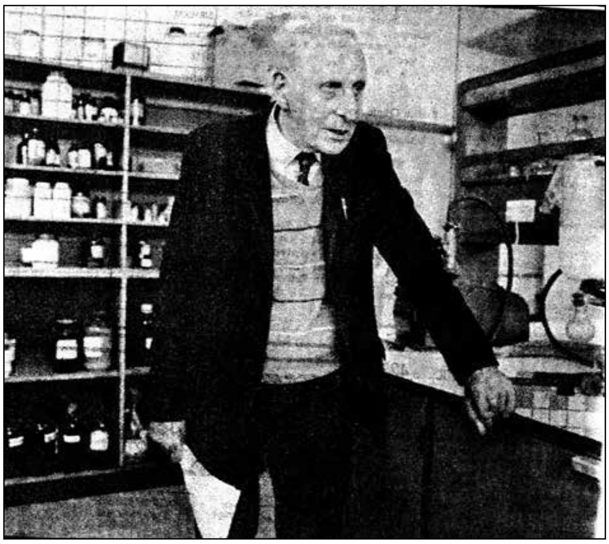

Brian Shorland – the Doyen of New Zealand Science, ca. 1995 (from *Brian Shorland – Doyen of New Zealand Science*, p. 131; courtesy of the New Zealand Association of Scientists).

Brian and Betty Shorland, 27 January 1938 (from *Brian Shorland – Doyen of New Zealand Science*, p. 143; courtesy of the New Zealand Association of Scientists).

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An ecosystem services approach to choosing environmental indicators for state of environment reports

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State of environment (SOE) reports aim to give people a summary of the environment through indicators. When an SOE report is associated with specific environmental goals, it is straightforward to develop indicators from the goals. However, it is difficult when there are no specific goals. We explore the use of an ecosystem services framework to develop a general set of indicators for the land/water environment by considering a full range of benefits humans gain from the environment. This analysis shows that the national SOE report, Environment Aotearoa, is missing many indicators required for a broader picture. Many of the missing impact indicators relate to human health and are highly relevant. Our sparse networks of data collection reflect the low population of New Zealand and the limited resources that can be reasonably applied to data collection. An encouraging area of improvement is the use of more targeted indicators developed from the ground up in collaboration with stakeholders. While the analysis presented here is focussed on New Zealand, other countries are also data-sparse and face similar issues, and would benefit from a gap analysis of environmental indicators based on ecosystem services.

Introduction

State of environment (SOE) reports aim to give people an objective summary of their environment. It is implicit that there will be a response to SOE reports if a negative trend or a poor condition is reported. If not, then the reports would have no purpose. Therefore, SOE reports are effectively part of an adaptive management cycle (Environment Foundation 2019), where environmental goals are monitored through the report, and management is adapted to ensure progress towards the goals (Fig 1). (Adaptive management is defined in the EEZ act.) For example, in the New Zealand Resource Management Act 1991 (section 35), local authorities are legally required to monitor the state of their environment in order to carry out effectively their functions of sustainably managing natural resources, which is the environmental goal.

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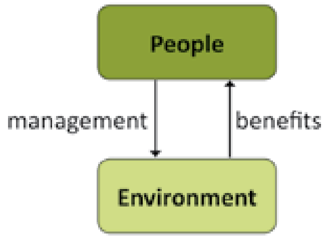
Figure 1. State of environment reporting helps people manage the environment to maintain or enhance its benefits.



State of environment reports usually have indicators, or measures, of important aspects of the environment. When an SOE report is associated with specific environmental goals, the important aspects may be inferred directly from the goals and it is straightforward to develop indicators. However, when there are no specific goals, it is more difficult to develop indicators (Garrett *et al.* 2016). So how does one go about designing a general set of indicators for an SOE report? An anthropocentric view, as in Fig 1, suggests there should be indicators of those environmental aspects that relate to human benefits. In other words, the indicators should follow the benefits or those aspects of the environment that closely relate to or control the benefits. A list of the benefits would therefore suggest a list of indicators.

The New Zealand national SOE report, Environment Aotearoa (Ministry for the Environment and Statistics New Zealand 2015), recognised this partly in the pressure-state-impact (PSI) framework prescribed by the Environmental Reporting Act (2015). Since Environment Aotearoa 2015, individual domain reports have been produced for marine, atmosphere and climate, freshwater, and land (Ministry for the Environment and Statistics New Zealand 2016, 2017a, 2017b, 2018)), and an air domain

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Anne-Gaëlle Ausseil is a scientist at Manaaki Whenua studying ecosystem services state and trends. She has worked with the Ministry for the Environment as a science advisor for Environmental Reporting, and has been part of a Treasury working group for assessing Natural Capital in the Living Standards Framework. She led the 'Innovative Data Analysis' programme, which developed techniques for recording provenance of indicators. Internationally, she is involved in the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES), as a coordinating lead author for the regional assessment of Asia-Pacific. Anne-Gaelle has a PhD in Agricultural Engineering from SupAgro in Montpellier.

report was produced prior to Environment Aotearoa 2015 (Ministry for the Environment and Statistics New Zealand 2014). Environment Aotearoa 2019 has just been released (Ministry for the Environment and Statistics New Zealand 2019). Pressures explain the human activities and natural factors that influence the environment. State indicators describe the biophysical condition of the environment. The impact indicators measure the impact that state indicators have on environmental benefits to people. In this way, relative importance can be attached to trends detected in the state indicators, and more appropriate and prioritised responses made. Categories of impacts are listed at a high level in the Act: public health, economy, culture and recreation, te ao Māori, and ecological integrity. However, it is not clear which specific indicators would satisfy the need to monitor those impact categories. Currently a technical advisory group recommends indicators to the Government Statistician who assesses them for use on the basis of six criteria (Ministry for the Environment 2016b), however there are no explicit criteria for guiding choice of indicators by the technical advisory group.

Rather than listing specific indicators in the Act, a process for defining topics is described. The Minister of the Environment and the Minister of Statistics set the topics through regulation after consultation with the Government Statistician, the Parliamentary Commissioner for the Environment, the public, iwi authorities, and local authorities. These topics need to satisfy several requirements, including affecting significant areas, resources or numbers of people, and are measurable. This process, while increasing buy-in from the community, through consultation, may be susceptible to disputes among pressure groups with different values.

Is there an objective way to develop a list of indicators that cover all aspects of the environment and closely relate to the benefits that the environment provides for people? Certainly there are explicit frameworks of benefits or services. The ecosystem services approach makes explicit the link between environment and human well-being (Millennium Ecosystem Assessment 2005). It has a detailed breakdown of benefits into categories of "ecosystem services" from each ecosystem in the area of interest. The services form a hierarchy, with provisioning, regulating, cultural, and supporting services at the top level, and increasing detail at the lower level. Dymond *et al.* (2015) presented a synopsis of New Zealand ecosystem services with analysis of their conditions and trends based on an extensive review from more than 100 New Zealand scientists (Dymond 2013), while Harmsworth and Awatere (2013) adapted the ecosystem services principles into a Māori framework.

The more recent Intergovernmental Platform on Biodiversity and Ecosystem Services (Diaz *et al.* 2015), initiated in 2012 to enhance global science policy, set a broader conceptual framework built on ecosystem services principles within diverse cultures. The conceptual framework included elements of PSI with drivers (such as population and land use), nature's contributions to people, and good quality of life. Thematic assessments for pollination, land degradation and restoration have been produced for four global regions (https://www.ipbes.net/document-library-categories/assessment-reports-and-outputs). These are all broad scale assessments, although some relevant information for New Zealand is included in the Asia-Pacific regional assessment (IPBES, 2018).

In this paper, we explore the use of the ecosystem services framework to develop objectively environmental indicators for the land domain of a national SOE report. For each broad ecosystem, the major ecosystem services are considered, and a set of pressures, states, and impacts derived. From these, explicit indicators are derived and then compared with those reported in Environment Aotearoa and subsequent domain reports. We discuss the difference between the two, and the implied requisite enhancements to Environment Aotearoa, from a science perspective (Petrie (2018) took a policy perspective). We also discuss implications of this approach to other environmental reporting systems in New Zealand.

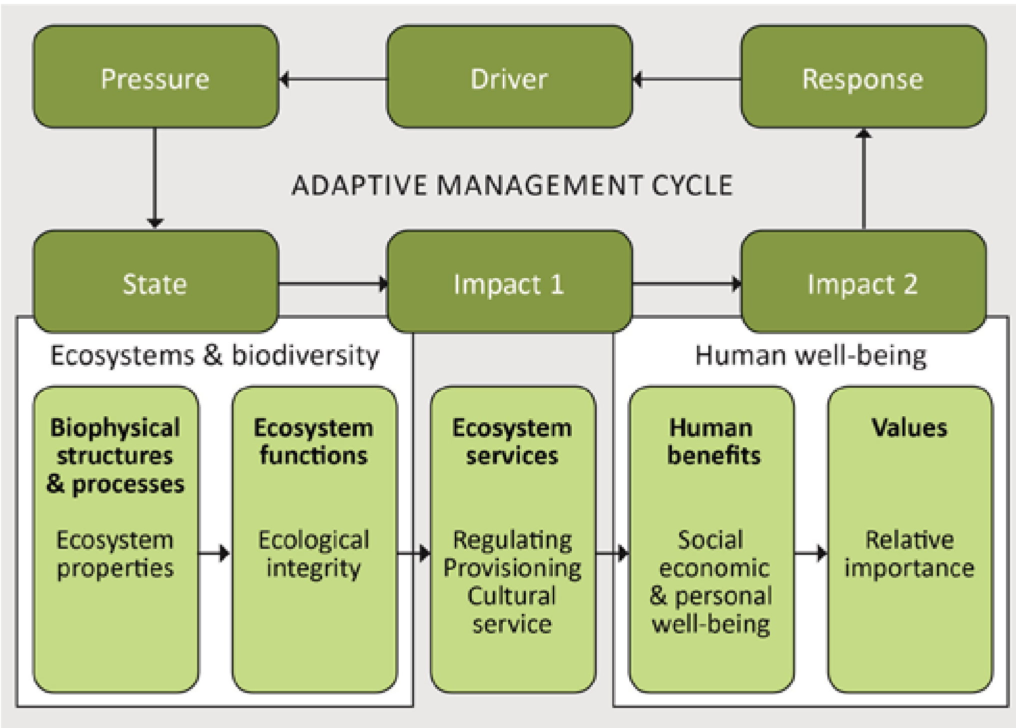

Figure 2. Relationship between pressure-state-impact and ecosystem services framework (Muller & Burkhard 2012).

Indicators of pressures, states, and impacts in ecosystems

The Driver-Pressure-State-Impact-Response (DPSIR) framework has been used for environmental reporting to describe causal links between elements of the broad environmental system (Müller & Burkhard 2012). The ecosystem services approach can easily fit into the DPSIR framework (see Fig 2). Pressure represents the elements (either anthropogenic or natural) that are affecting the state of ecosystems and can be either positive or negative (Ministry for the Environment 2014). State represents the natural capital stocks of ecosystems and biodiversity, characterised by their area and condition. Impacts are then two-fold: on ecosystem services (regulating, provisioning and cultural), and on human well-being (social, economic, personal).

The methodology we used separates major ecosystems into broad categories: including urban, pasture, cropping, orchard, exotic forest, indigenous forest, shrublands, grassland, alpine shrublands, rare ecosystems and wetlands (Harmsworth and Awatere 2013). The Ministry for the Environment (MfE) adopted the pressure-state-impact (PSI) framework, omitting drivers (D) and responses (R) on purpose to maintain political neutrality.

Table 1 tabulates the major pressures, states, and impacts for each ecosystem as essentially described in a national assessment of ecosystem services (Dymond 2013). The ecosystem classification follows that of Harmsworth and Awatere (2013). Table 2 tabulates quantitative measures of the pressures, states, and impacts that could be used as indicators. The solid colour in Table 2 identifies where the indicator has actually been used in Environment Aotearoa reporting, or is readily available in a nationally based dataset.

Immediately obvious is the sparse population of Table 2 by indicators in Environment Aotearoa. There are a number of reasons behind the sparseness of Table 2 beyond the control of officials in Ministry for the Environment and Statistics New Zealand. The Environmental Reporting Act in section 14 stipulates that the Government Statistician must follow best practice principles and protocols and be satisfied that the statistics accurately represent the topic they purport to measure. This required statistical rigor has meant that some indicators have not come up to expectations in the eyes of the Government Statistician. For example, in the SOE report, Environment New Zealand 2007 (Ministry for the Environment, 2007), the number of contaminated sites (land) was previously reported by region, but is not reported in Environment Aotearoa, even though an updated national dataset existed. This was due to the lack of consistency of reporting between regions as required by the high statistical rigor.

High statistical rigour gives more surety about trends, and should reduce arguments over whether trends show improvements or not (Radio New Zealand 2014). However, it also means that much information pertinent to understanding the full state of the environment is not considered. The Parliamentary Commissioner for the Environment (PCE 2016), in exercising her discretion under section 18 of the Environmental Reporting Act, reviewed Environment Aotearoa 2015 and commented that a national SOE report should be a set of coherent "stories" about different issues. Stories, of course, require complete narratives, and the concept flies in the face of the requirement for statistical rigor which rejects parts of the story. Following Environment Aotearoa 2015 and the PCE commentary, MfE has included more storylines in subsequent domain reports, by using body of evidence and case study information from scientific literature, and by establishing Technical Advisory Groups to inform MfE of recent research findings. In doing so, the Land domain report 2018 (Ministry for the Environment, 2018) highlighted the significant data gaps impeding reporting. These included gaps in scientific knowledge (understanding of processes and causal links between pressure and state), gaps in spatial coverage and trends over time (e.g. land use, soil health), and gaps on impacts on social, cultural and economic wellbeing.

Table 2 is sparse also because of the great effort required in gathering data. Section 11 of the Environmental Reporting Act relieves the Secretary for the Environment and Government Statistician of having to collect data where it cannot be obtained by using reasonable efforts. Unfortunately, much of the data required to populate Table 2 would require extraordinary efforts. For example, the pressure indicator "Area of cultivated land" in the cropping ecosystem is currently determined by the Agricultural Production Survey that is non-spatial and constrained to commercial-scale farms. Some spatial information is available but requires licensing, which is against the principles of publicly publishing any reporting data. Another method for determining cultivated land from publicly available data sources could be from sequential satellite imagery (North *et al.* 2015). However, the effort required setting up new systems to automatically identify the cultivated land and report at appropriate time and space scales is significant and currently well beyond that judged reasonable.

Many of the missing desired impact indicators relate to human health and are highly relevant. For example, in the urban ecosystem it would be desirable to know how many illnesses relate to freshwater contaminated by untreated sewerage. To capture a fuller understanding of the issue it would also be desirable to measure the annual volume of contaminated water in the district and also the toxicity of the receiving water. These indicators are missing because data collection is absent. Our sparse networks of science data collection reflect the low population of New Zealand and the resources that can be reasonably applied to data collection.

Discussion

Is it likely that the missing indicators in Table 2 will be included in future SOE reports? Even though data for many indicators already existed elsewhere in national databases, the cost of re-analysis and representation is high to meet statistical robustness and suitability for public consumption. The exact cost is difficult to estimate, but is likely to be tens of millions of dollars and may be stretching the taxpayer's perspective of reasonable effort. It looks unlikely, therefore, that many more of the missing indicators will appear in the near future, as it would take years to fill the gaps. What does that mean in the short to medium term if we are unable to get a comprehensive look at our environment and adapt our management for our own benefit?

Let us not allow to pass unchallenged the contention that Environment Aotearoa is the sole reliable source of environmental data. Indeed, there is much environmental monitoring in the land/water space at local scales (Garrett *et al.* 2016). There are many successful local projects where communities are involved with setting goals and indicators. In the Canterbury region, water zone committees, comprising sector representatives, local body representatives, and technical staff from the regional

Table 1. Pressures, states, and impacts in the major land ecosystems in New Zealand.

Ecosystem	*Pressure_1*	*Pressure_2*	*State*	*Impact*
Urban	Waste treatment		Contaminated land	Human health risk, loss of land utility
	Waste production		Land fill	Human health risk, loss of land utility
	Air pollution		Particulates in air	Low air quality
	Sewerage treatment		Contaminated discharge	Low water quality
	Urban runoff		Contaminated discharge	Low water quality
	Urbanisation		Productive land	Loss of utility value
	Weeds/pests		Weed spread, pest invasion	Habitat loss, reduced productivity
Pasture	Animal grazing	Nitrate leaching	Nitrate in waterways	Low water quality
		Fertiliser loss	Dissolved N and P in waterways	Low water quality
		Egestion	E. coli in waterways	Low water quality
		Soil treading	Soil compaction	Reduced productivity
		Treading of riverbanks	Soil erosion	Low water quality, sedimentation of waterways
	Land use change	Forest clearance	Soil erosion	Low water quality, reduced productivity, sedimentation
	Waste treatment		Contaminated land	Human health risk, loss of land utility
	Weeds/pests		Weed spread, pest invasion	Habitat loss, reduced productivity
Cropping	Cropping	Fertiliser loss	Dissolved N and P in waterways	Low water quality
		Cultivation/harvesting	Soil compaction, disturbance, and erosion	Reduced productivity
		Weed control	Herbicides in environment	Lower human health
		Pest control	Pesticides in environment	Lower human health
	Weeds/pests		Weed spread, pest invasion	Habitat loss, reduced productivity
Orchard	Horticulture	Fertiliser loss	Dissolved N and P in waterways	Low water quality
		Weed control	Herbicides in environment	Lower human health
		Pest control	Pesticides in environment	Lower human health
	Weeds/pests		Weed spread, pest invasion	Habitat loss, reduced productivity
Exotic forest	Forestry	Harvesting	Soil compaction, disturbance and erosion.	Reduced productivity
		Weed control	Herbicides in environment	Lower human health
		Pest control	Pesticides in environment	Lower human health
	Land use change	Forest clearance	Soil erosion	Low water quality, reduced productivity, sedimentation
	Waste treatment		Contaminated land	Human health risk, loss of land utility
	Weeds/pests		Weed spread, pest invasion	Habitat loss, reduced productivity

Table 1. Pressures, states, and impacts in the major land ecosystems in New Zealand (*continued*).

Indig. forest	Deforestation	Habitat loss	Reduced biodiversity
		Soil erosion, carbon loss.	Low water quality, climate change
	Mineral extraction	Land disturbance	Reduced biodiversity, low water quality
	Gas extraction	Land disturbance	Reduced biodiversity, low water quality
	Weeds/pests	Degraded habitat	Reduced biodiversity, reduced amenity value
	Tourism	Degraded habitat	Reduced biodiversity, reduced amenity value
Shrublands	Clearance	Habitat loss	Reduced biodiversity
		Soil erosion, carbon loss.	Low water quality, climate change
	Mineral extraction	Land disturbance	Reduced biodiversity, low water quality
	Gas extraction	Land disturbance	Reduced biodiversity, low water quality
	Weeds/pests	Degraded habitat	Reduced biodiversity, reduced amenity value
	Tourism	Degraded habitat	Reduced biodiversity, reduced amenity value
	Excess honey collection	Reduced nectar supply	Reduced biodiversity
Grassland	Conversion to pasture	Habitat loss	Reduced biodiversity, reduced amenity value
	Mineral extraction	Land disturbance	Reduced biodiversity, low water quality
	Gas extraction	Land disturbance	Reduced biodiversity, low water quality
	Weeds/pests	Degraded habitat	Reduced biodiversity, reduced amenity value
	Tourism	Degraded habitat	Reduced biodiversity, reduced amenity value
	Excess animal grazing	Land degradation	Reduced productivity, biodiversity, amentiy value
Alpine shrubland	Weeds/pests	Degraded habitat	Reduced biodiversity, reduced amenity value
	Tourism	Degraded habitat	Reduced biodiversity, reduced amenity value
Rare ecosystems	Land use	Habitat loss	Reduced biodiversity
	Weeds/pests	Degraded habitat	Reduced biodiversity
Wetlands	Drainage	Habitat loss	Reduced biodiversity, water reg. ,wild food, amenity
	Nutrient /sediment runoff	Wetland degradation	Reduced biodiversity, wild food, amenity value
	Weeds/pests	Degraded habitat	Reduced biodiversity, amenity value

Table 2. Indicators of pressures, states, and impacts in the major land ecosystems in New Zealand.*

Ecosystem	*Desired pressure indicator*	*Desired state indicator*	*Desired impact indicator*
Urban	No. of contaminated sites in district	No. of unmanaged sites per district	No. of related illnesses per district
	Waste to landfills in district, population in district	% of waste effectively managed	No. of related illnesses per district, land area of un-utilisable land
	Annual burning pressure (t/yr) in district	Seasonal average particulate concentrations	No. of related illnesses per district
	Annual volume of untreated sewerage in district	Toxicity of water	No. of related illnesses per district
	Annual volume of contaminated discharge in district	Toxicity of water	No. of related illnesses per district
	Population in region	Area of utilisable high class land	% of high class land under lifestyle and urban
	List of noxious weeds/pests in district	Area of parks and gardens free of noxious weeds/pests	Cost of noxious weeds in district
Pasture	Animals in region	Annual nitrate load in region	Average nitrate concentration in water at selected sites
	Fertiliser use in region	Annual total P load in region	Average total-P concentration in water at selected sites
	Cattle in region with access to waterways	Annual total E. coli load in region	Median *E. coli* concentration in water at selected sites
	Cattle in region with access to waterways	Length of eroded riverbanks (region)	Sediment load to rivers from banks in region
	Cattle on soils at risk of compaction (per region)	Area of compacted soils, % of compacted soils	Gross regional agricultural production
	Forest clearance in region	Area of land at risk of erosion (region)	Sediment load to rivers in region, average soil erosion in region
	No. of contaminated sites in region	No. of unmanaged sites per region	No. of related illnesses per region
	List of noxious weeds/pests in region	Area of infestation per weed/pest (region)	Area free of weeds and pests (natural and managed)
Cropping	Fertiliser use in region	Contribution to annual total P load in region	Average total-P concentration in water at selected sites
	Area of land cultivated in region	Proportion of soils not meeting target	Gross output per hectare in region
	Mass of herbicide sprayed per year in region	Herbicide concentration in environment	No. of related illnesses per region
	Mass of pesticides sprayed per year in region	Pesticide concentration in environment	No. of related illnesses per region
	List of noxious weeds/pest for cropping in region	Area of infestation per weed/pest (region)	Proportion of cropping land free of weeds/pests
Orchard	Fertiliser use in region	Contribution to annual total P load in region	Average total-P concentration in water at selected sites
	Mass of herbicide sprayed per year in region	Herbicide concentration in environment	No. of related illnesses per region
	Mass of pesticides sprayed per year in region	Pesticide concentration in environment	No. of related illnesses per region
	List of noxious weed/pests for horticulture in region	Area of infestation per weed/pest (region)	Proportion of horticulture land free of weeds/pests in region
Exotic forest	Harvested area	Proportion of soils not meeting target, average soil erosion, carbon stocks	Gross output per hectare in region, contribution to sediment load
	Mass of herbicide sprayed per year in region	Herbicide concentration in environment	No. of related illnesses per region
	Mass of pesticides sprayed per year in region	Pesticide concentration in environment	No. of related illnesses per region
	Forest clearance in region	Area of land at risk of erosion (region)	Sediment load to rivers in region, average soil erosion in region
	Land area of waste treatment (district)	Area of ineffective waste treatment (district)	No. or related illnesses per district
	List of noxious weeds/pests for forestry in region	Area of infestation per weed/pest (region)	Proportion of forestry free of weeds/pests (region)

Table 2. Indicators of pressures, states, and impacts in the major land ecosystems in New Zealand (*continued*).

Indig. forest	Area of forest cleared	Number of threatened land environments	Conservation status of indigenous species
		Area of land at risk of erosion (region), Carbon stocks	Sediment load to rivers in region, average soil erosion in region
	Area of mining activity	Area of disturbed land	No. of threatened rare environments
	Area of gas extraction	Area of disturbed land	No. of threatened rare environments
	List of noxious weeds/pests in region	Area of infestation per weed/pest (region)	Area free of weeds and pests
	Visitor numbers	Area impacted by visitors	Amenity value
Shrublands	Area of shrubland cleared	Number of threatened land environments	Conservation status of indigenous species
		Area of land at risk of erosion (region)	Sediment load to rivers in region, average soil erosion in region
	Area of mining activity	Area of disturbed land	No. of threatened rare environments
	Area of gas extraction	Area of disturbed land	No. of threatened rare environments
	List of noxious weeds/pests in region	Area of infestation per weed/pest (region)	Area free of weeds and pests
	Visitor numbers	Area impacted by visitors	Amenity value
	Honey bee hive numbers in shrublands	Floral resources available for indigenous species	Conservation status of indigenous species
Grassland	Area of tussock grassland converted	No. of threatened land environments	Conservation status of indigenous species
	Area of mining activity	Area of disturbed land	No. of threatened rare environments
	Area of gas extraction	Area of disturbed land	No. of threatened rare environments
	List of noxious weeds/pests in region	Area of infestation per weed/pest (region)	Area free of weeds and pests
	Visitor numbers	Area impacted by visitors	Amenity value
	Animal stocking rates	Area of degraded land	Productivity, amenity value
Alpine shrubland	List of noxious weeds/pests in region	Area of infestation per weed/pest (region)	Area free of weeds and pests
	Visitor numbers	Area impacted by visitors	Amenity value
Rare ecosystems	Area of land use intensification/change	No. of threatened rare environments	Conservation status of indigenous species
	List of noxious weeds/pests in rare environments	No. of threatened rare environments	Conservation status of indigenous species
Wetlands	Area of wetlands drained	Proportion of wetlands remaining	Cons. status of indigenous species, amenity value, wild food harvest
	Nutrient/sediment discharge to wetlands	Condition of wetlands	Cons. status of indigenous species, amenity value, wild food harvest
	List of noxious weeds/pests in wetlands	Condition of wetlands	Cons. status of indigenous species

*A solid colour identifies where the indicator has actually been used in Environment Aotearoa reporting, or is readily available in a nationally based dataset. No colour identifies indicators not used in Environment Aotearoa, because complete data is unavailable. Shaded cells have some body of evidence but no indicator.

council, have been set up to develop water management plans. This initiative has followed the recommendations of the Land and Water Forum (2015), which has promoted collaborative processes involving community and stakeholders for managing water, a bottom-up approach within nationally set frameworks. Such initiatives are supported by monitoring information presented by Land Air Water Aotearoa (2016), which is a web site, organised primarily by regional and district councils, for giving information on land, air, and water quality.

The New Zealand Sustainability Dashboard (http://www.nzdashboard.org.nz/) has developed processes for primary production sectors to assess sustainability. The process is driven by the producers/farmers to achieve sustainability goals both for individual producers and for sectors as a whole after upscaling to regional and national scales. Case studies involve wine, kiwifruit, forestry, and organic sectors. This is another example of a bottom-up approach to the national sector scale, which has strong buy-in from users because of collaborative processes with stakeholders. Another example is the Waikato River Report Card (Waikato River Authority 2016), which summarises progress towards goals of Ture Whaimana o Te Awa o Waikato. Development of the report card engaged local community and provides accountability for restorative actions in the Waikato catchment. It synthesises complex information at local scales into simple key messages for the whole catchment. Further notable projects include the Wheel of Water Project (2016) on balancing water quality and quantity and the Montreal Process for the development of indicators for sustainable forestry (Ministry for Primary Industries 2015).

There are many local body SOE reports: Environment Canterbury 2008; Greater Wellington Regional Council 2013; Waikato District Council 2013; Bay of Plenty Regional Council 2014; Horizons Regional Council 2013. These reports are comprehensive, covering land, water, air, biodiversity, pests, and hazards. Yet much of this data does not make its way up to the national scale because of inconsistencies between regions. This has been recognised, so the Environmental Monitoring and Reporting project (EMaR) has been set up to provide support to regional councils to standardise methods and sharing of data collection through initiatives such as the National Environmental Monitoring Standards (NEMS). The goal of EMaR is to ensure that the efforts in compiling regional data will inform national SOE reporting.

Much is indeed being done at the local scale, but not consistently throughout the country. This inconsistency creates difficulties for Environment Aotearoa with its emphasis on statistical robustness rather than storyline, causing it to miss many important indicators in Table 2. A reporting system that includes all the local stories rather than excluding them is necessary to ensure a link between bottom–up and top–down approaches. Some New Zealand studies have already done this. The Waikato River Report Card shows how a hierarchy of data can be integrated up to simple scores at the top reporting level. Where data are missing, expert judgement is used so that integration may proceed. While simple scores are presented at the top level, the full hierarchy of data is retained and may be interrogated at any level. A recent scoping study for MfE on Te Ao Māori environmental indicators suggested that case studies, narratives, and commentaries are an important part of environmental reporting (Scheele *et al.* 2016). This is also one of the recommendations coming from the research community. A think-piece commissioned by Our land and Water, the National Science Challenge, highlighted the benefits of co-innovation for development of land and water indicators (Garrett *et al.* 2016). It concluded that success of bottom–up approaches depend on collaboration and co-innovation. Our Land and Water has initiated a working group examining the development of indicators, considering the history of indicator frameworks already developed in New Zealand in order to produce a cohesive set of land and water indicators for multiple stakeholders.

Environment Aotearoa is constrained by the Environmental Reporting Act to ensure statistical robustness. As a result, many indicators are not being covered and complete stories are not being told. Even with more comprehensive coverage of pressure, state, and impact indicators in Table 2, the full story may still not be covered. Niemeijer and de Groot (2008) advocated the DPSIR framework to provide a better context in which to plan appropriate responses. So at the national scale it appears that we need more and more indicators, which come at a greater cost than that deemed "reasonable" by the Environmental Reporting Act. The solution is to build indicators from the ground up in collaboration with stakeholders to ensure buy-in at the start (Garrett *et al.* 2016). Dymond et al. (2001) called this strategic monitoring, whereby environmental goals are monitored. While National Science Challenges are working towards this goal, there is a long way to go before a comprehensive picture of our land and water environment can be drawn. While the analysis presented here has focussed on New Zealand, other countries are also data-sparse and face similar issues (Geijzendorffer *et al.* 2015; Heink *et al.* 2016), and would benefit from a gap analysis of environmental indicators based on ecosystem services.

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Comments

Hodder (2018): 'Independent scientific research entities in New Zealand', Table 9

There have been numerous tweets about the discrepancies between Table 9 in Peter Hodder's paper: 'Independent scientific research entities in New Zealand: Cawthron Institute as a case study' (Hodder 2018) and current practice in the National Science Challenges.

Of these comments, Professor Sally Davenport (at right) has the observation that 'Things have moved quickly from establishment days', which best reflects the simple cause of the mismatch between Table 9, compiled from MBIE (2016), and the current situation in 2019 (MBIE 2019).

Dr Hodder has updated the previous version (Hodder 2018: 15) as Tables 9.1 and 9.2, with the following commentary. From this it is apparent that the 'challenges' continue to be collaborative within and between universities, Crown Research Institutes, and the smaller 'players' – Government agencies and private research institutions.

As before, the number of challenges in which an organisation participates remains a function of its size (Figure 1A), albeit supporting the earlier suggestion of an optimum size of institution that participates in such challenges (Hodder 2018: 13). The same trend is apparent in funding (Figure 1B).

In this context, institutional size can be considered a proxy for research capability. For the universities the Performance-Based Research Fund (PBRF) score is a measure of research capability and this is positively correlated with the number of challenges in which each university participates and the funding (Figure 2).

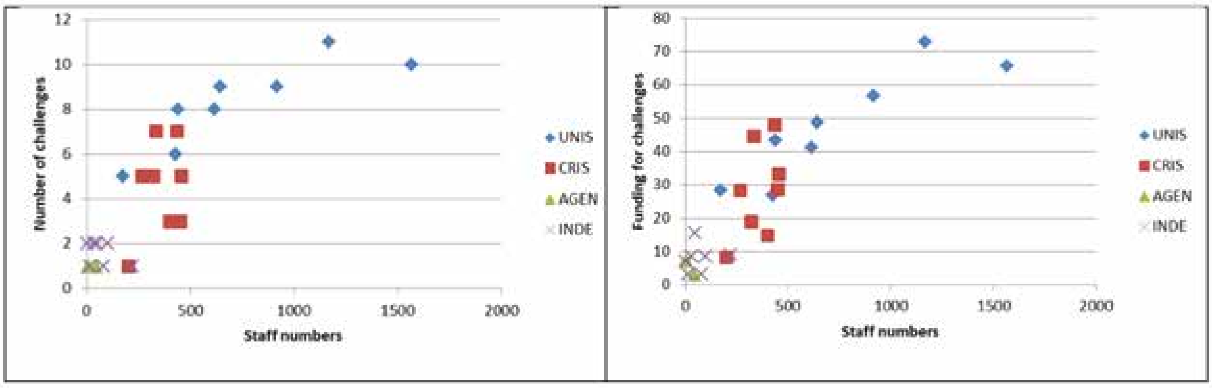

Figure 1. Variation of number of challenges with A (left) institutional size, and B (right) funding for challenges with institutional size (Legend: UNIS, Universities; CRIS, Crown Research Institutes, AGEN, Government / Local government agencies; INDE, Independent institutions.)

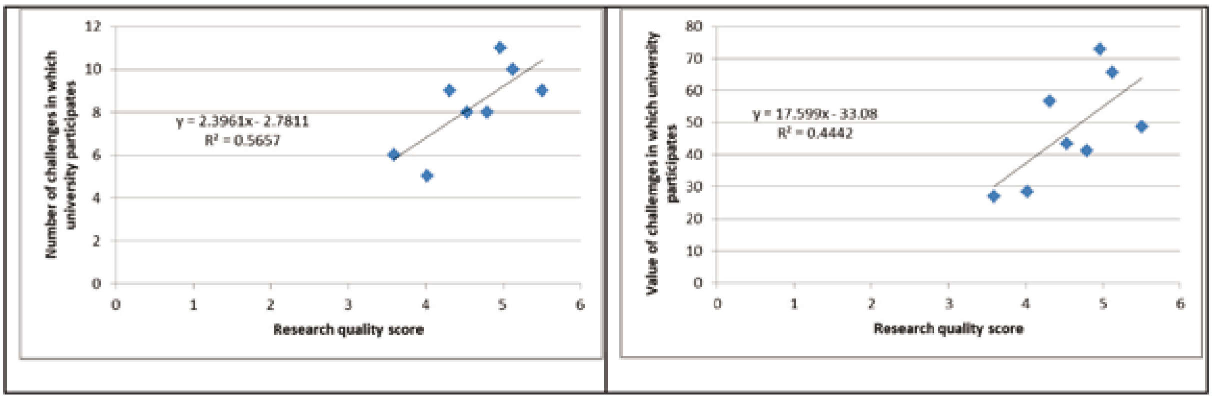

Figure 2. Variation of number of challenges with A (left) institutional size, and B (right) funding for challenges with research quality score for universities in the 2012 round of the PBRF.

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Table 9.1 Collaboration partners (●) and hosts (■)	National Science Challenges*											Σ
	1	2	3	4	5	6	7	8	9	10	11	
Universities												
Auckland University of Technology	●	●	●	●		●			●			*6*
Lincoln University			●			●	●	●	●			*5*
Massey University	●	●	●	●	●	●	●	●	●			*9*
University of Auckland	■	●	●	●	■	●	●	●	●	●		*10*
University of Canterbury	●	●	●	●		●		●	●	●		*8*
University of Otago	●	■	●	■	●	●	●	●	●	●	●	*11*
University of Waikato	●	●	●	●		●	●		●	●		*8*
Victoria University of Wellington	●	●	●	●		●		●	●	●	●	*9*
Subtotal: All participating universities	*7*	*7*	*8*	*7*	*3*	*8*	*5*	*6*	*8*	*5*	*2*	*66*
Crown Research Institutes												
AgResearch	●	●		●	●	●	■		●			*7*
Callaghan Innovation									■			*1*
Institute of Environmental Science Research				●		●	●					*3*
Institute of Geological and Nuclear Sciences			●			●	●	■	●	●	●	*7*
Landcare Research						■	●				●	*5*
National Institute of Water and Atmospheric Research						●	●	●		■	■	*5*
Plant and Food Research					●	●	●					*3*
Scion			●			●	●	●	●			*5*
Subtotal: All participating CRIs	*1*	*1*	*2*	*2*	*2*	*7*	*7*	*3*	*4*	*2*	*3*	*34*
Government / local government agencies												
NZ Antarctic Research Institute											●	*1*
Antarctic New Zealand											●	*1*
Auckland Council Research Investigation and Monitoring Unit (RIMU)			●									*1*
Subtotal: All participating agencies	*0*	*0*	*1*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*2*	*3*
Independent institutions												
Building Research Association of New Zealand (BRANZ)			■					●				*2*
Cawthron Institute										●		*1*
Centre for Research Evaluation and Social Assessment (CRESA)		●	●									*2*
Lincoln Agritech							●		●			*2*
Malaghan Institute				●								*1*
Opus International Consultants			●					●				*2*
Prefab New Zealand			●									*1*
Subtotal: All participating independent institutions	*0*	*1*	*4*	*1*	*0*	*0*	*1*	*2*	*1*	*1*	*0*	*11*
Total: All collaboration partners and hosts	8	9	15	10	5	15	13	11	13	8	7	114
Funding (millions of dollars, over ten years)	34.7	34.9	47.9	31.3	83.8	63.7	96.9	59.4	106	71.1	51.1	680.8
Funding per collaboration partner (notional,† over ten years)	4.38	3.88	3.19	3.13	16.8	4.25	7.45	5.40	8.15	8.89	7.3	5.97

* *National Science Challenges*

1 **A Better Start | E Tipu e Rea** aims to improve the potential for young New Zealanders to have healthy and successful lives;

2 **Ageing Well | Kia eke kairangi ki te taikaumātuatanga** is researching how to sustain health and well-being as people age, enabling all New Zealanders to reach their full potential into the later years of life;

3 **Building Better Homes, Towns and Cities | Ko ngā wā kāinga hei whakamāhorahora** aims to improve the quality and supply of housing and create smart and attractive urban environments;

4 **Healthier Lives | He Oranga Hauora** is undertaking innovative research aimed at significantly reducing the death and disease burden of some of New Zealand's leading health problems;

5 **High-value Nutrition | Ko Ngā Kai Whai Painga** will enable the transformation of New Zealand's food and beverage industry to become an exporter of high-value foods with scientifically proven health benefits;

6 **New Zealand's Biological Heritage | Ngā Koiora Tuku Iho** aims to protect and manage New Zealand's biodiversity, improve our biosecurity, and enhance our resilience to harmful organisms;

7 **Our Land and Water | Toitū te Whenua, Toiora te Wai** aims to enhance the production and productivity of New Zealand's primary sector, while maintaining and improving the quality of the country's land and water for future generations;

8 **Resilience to Nature's challenges | Kia manawaroa - Ngā** Ākina **o Te Ao Tūroa** is enhancing New Zealand's ability to anticipate, adapt and thrive in the face of ever-changing natural hazards;

9 **Science for Technological Innovation | Kia kotahi mai - Te Ao Pūtaiao me Te Ao Hangarau** aims to tackle New Zealand's big high-tech challenges to grow the economy;

10 **Sustainable Seas | Ko ngā moana whakauka** is focused on enhancing the use of New Zealand marine resources within environmental and biological constraints;

11 **The Deep South | Te Kōmata o Te Tonga** is working to understand the role of the Antarctic and Southern Ocean in determining New Zealand's future climate and how the impact this role has on key economic sectors, infrastructure and natural resources.

† Assuming the funding for each challenge is divided equally across all collaboration partners and hosts

Table 9.2 Collaboration partners and hosts	No. of challenges*	Value of challenges*	Capability measures	
			Staff†	
Universities				*PBRF score‡*
Auckland University of Technology	6	26.98	429.47	3.59
Lincoln University	5	28.44	174.10	4.02
Massey University	9	56.63	918.62	4.31
University of Auckland	10	65.52	1565.48	5.12
University of Canterbury	8	41.27	617.06	4.79
University of Otago	11	72.82	1168.24	4.96
University of Waikato	8	43.32	440.63	4.53
Victoria University of Wellington	9	48.57	641.54	5.51
Subtotal: All participating universities	*66*	*383.55*	*5955.14*	
Crown Research Institutes				
Ag Research	7	48.04	436	
Callaghan Innovation	1	8.15	200	
Institute of Environmental Science Research (ESR)	3	14.83	400	
Institute of Geological and Nuclear Sciences (GNS)	7	44.63	332	
Landcare Research	5	19	321	
National Institute of Water and Atmospheric Research (NIWA)	5	33.29	454	
Plant and Food Research	3	28.5	453	
Scion	5	28.44	269	
Subtotal: All participating CRIs	*34*	*224.88*	*2865*	
Government / local government agencies				
NZ Antarctic Research Institute	1	7.3	5	
Antarctic New Zealand	1	7.3	7	
Auckland Council Research Investigation and Monitoring Unit (RIMU)	1	3.19	43	
Subtotal: All participating agencies	*3*	*17.79*	*55*	
Independent institutions				
Building Research Association of New Zealand (BRANZ)	2	8.59	100	
Cawthron Institute	1	8.89	220	
Centre for Research Evaluation and Social Assessment (CRESA)	2	7.07	3	
Lincoln Agritech	2	15.6	50	
Malaghan Institute	1	3.13	81	
Opus International Consultants	2	8.53	34	
Prefab New Zealand	1	3.19	14	
Subtotal: All participating independent institutions	*11*	*55.00*	*502*	

***Number and value of challenges:** From Table 9.1

† Staff:

Universities: Taken as PBRF eligible staff from *Performance-Based Research Fund Evaluating Research Excellence – the 2012 Assessment* (Wellington; Tertiary Education Commission, 2013), p. 89-5.

Crown Research Institutes: AgResearch: Calculated from data in *Four Year Rolling Review: AgResearch Report from the Review Panel*, 2016, p. 35, https://www.mbie.govt.nz/assets/4f291b43cd/agresearch-4-year-rolling-review.pdf; Callaghan Innovation, About us, https://www.callaghaninnovation.govt.nz/about-us; ESR: "ESR employs around 400 expert minds", https://www.esr.cri.nz/our-people/our-science-team/; GNS: "Over 85% of our [390] staff are directly involved in science", https://www.gns.cri.nz/Home/About-Us/Structure-People; Landcare: https://www.landcareresearch.co.nz/about/people/science-teams; NIWA: "NIWA has more than 590 staff located throughout New Zealand and overseas", https://www.niwa.co.nz/about/our-people, of which the Annual Report 2018 notes 76.9% are scientists or technicians, https://www.niwa.co.nz/static/web/NIWA13387_2018-Annual-Report_13LR_Web.pdf; Plant and Food Research: "We have over 900 people, 75% of who are working in our science operations teams", https://www.plantandfood.co.nz/page/our-people/; Scion: Key science roles, https://www.scionresearch.com/about-us/about-scion/our-people; Scion: 321 staff in 2018, https://www.scionresearch.com/__data/assets/pdf_file/0009/64899/Scion_2018_AR_PartA.pdf , website shows 44 'key science roles', 5 'key operational roles', if the same ratio prevails across Scion, the number of scientists is estimated to be 269.

Government / local government agencies: NZ Antarctic Research Institute (a co-ordinating agency): Prospectus, p. 7, https://nzari.aq/images/downloads/NZARI%20Prospectus%202017_WebPDF_low%20res.pdf; Antarctic New Zealand (a co-ordinating agency): 'Our people', http://www.antarcticanz.govt.nz/about-us/our-people/; Auckland Council Research Investigation and Monitoring Unit (RIMU): http://www.knowledgeauckland.org.nz/assets/Uploads/RIMU-Capability-Statement-Email-19-03-18.pdf

Independent research institutes: BRANZ: "around 100 highly trained specialist staff", https://www.branz.co.nz/cms_display.php?sn=401&st=1; Cawthron Institute: 220, https://www.cawthron.org.nz/analytical-services/news/2018/reflections-cawthrons-longest-serving-employee/, "194 staff employed" from Cawthron Institute Annual Report 2012, p. 17, (https://www.cawthron.org.nz/media_new/publications/pdf/2013_08/Cawthron_Annual_Report_2012.pdf; CRESA (a co-ordinating and collaborative organisation): Our people, https://cresa.co.nz/our-people/; Lincoln Agritech: Who we are, https://www.lincolnagritech.co.nz/about/organisation; Malaghan Institute: Our people, https://www.malaghan.org.nz/our-history/our-people/ Of the "+90" staff referred to on the website, the Annual Report 2018 indicates 90% of the staff are in science-related occupations (https://www.malaghan.org.nz/assets/Uploads/Documents/Annual-Reports/Malaghan-Annual-Report-2018-12.0-CP-web.pdf); Opus International Consultants – Opus NZ: https://www.wsp-opus.co.nz/services/research/our-people/; Prefab NZ: http://www.prefabnz.com/About/People

‡ PBRF scores from *Performance-Based Research Fund Evaluating Research Excellence – the 2012 Assessment* (Wellington; Tertiary Education Commission, 2013), p. 89-5.

Book Review

Mike Joy (ed)

Mountains to the Sea:
Solving New Zealand's Freshwater Crisis

Reviewed by Troy Baisden*

Mike Joy has become a scientist known widely by Kiwis because he regularly sticks his head above the parapet to argue for our freshwater environments and the critters that live in them. The new book he has edited aims to sidestep arguments and focus on finding ways of thinking that lead to solutions. The title *Mountains to the Sea: Solving New Zealand's Freshwater Crisis* should cause any reviewer to ask whether the authors truly deliver solutions. Perhaps unsurprisingly, the answer is both: yes, and no.

In its best moments, the work will remind science readers holding PhDs that they share doctorates in philosophy with the humanities, and scientists can deliver much more to society, culture and the environment by embracing a liberal arts or philosophical approach to identifying and solving problems. In its weaker chapters, this approach becomes a double-edged sword, highlighting inaccuracies and disconnects in ways that weaken the book as a singular product advocating a way forward.

Let's be clear. The most provocative thing about Mike Joy is that he's a self-described advocate for freshwater ecosystems. He is absolutely an advocate, but for the parts of nature that can't speak for themselves on television news or social media. The book succeeds where the motivation of the author(s) comes through clearly, and Joy takes the lead by introducing the book's perspective deftly.

However, the polarised public perception of Joy and his work means that a review should back up and ask: Why is defining motivation the right thing to do in environmental science? There are still many who think scientists should stick to science, or have gone off the rails if they're not so-called 'honest brokers'. Would I suggest readers with this perspective avoid Joy's book?

I'd tend to suggest exactly the opposite. Anyone who can approach the book with an open mind will learn from it. Yet, when it comes to declaring motivation, we have only starting points to an approach that has emerged but not yet been fully documented and embedded in academic institutions. In my own doctoral journey at Berkeley, in the formative years of what is now a top-ranked environmental science programme, I learned that the applied side of environmental science requires gaining enough perspective from the social sciences and

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humanities to declare more than methods and funding. Perspectives, path, and perhaps even epistemology matter for all interdisciplinary endeavours. Among interdisciplinary fields, including health sciences, the benefits of declaring motivation are rather unique for environmental science, because of the focus on human interactions with aspects of nature that do not speak for themselves. Documenting what worked at Berkeley, Andrade *et al*. (2014) noted that success of the 20-year-old interdisciplinary programme contrasts strongly "with the received wisdom of the scientific method as a sacred, objective ritual that leads inevitably to 'Big "T" truth'".

We have come in the last few years to accept scientists in climate change science declaring their advocacy, in the face of political inaction. A generation ago, the noted climate scientist Stephen Schneider was relatively unique in having taken that prophetic approach (Schneider 1988; Russill 2010). Schneider's approach to advocacy can serve as a legitimate end-member of a spectrum that runs from pure science to advocacy (Donner *et al*. 2014). It strikes me that Joy has taken Schneider's path on freshwater. Joy's introduction and many better chapters pass Donner's test of declaring motivations to define a location on the 'science–advocacy continuum'.

In this review, it is useful to focus on Nick Kim's chapter on agricultural contaminants because it breaches Donner's test in two ways. At the outset, it frames a straw person argument of tourists in the New Zealand landscape expecting a true wilderness. Such a perspective hasn't been academically viable after Bill McKibben's book *The End of Nature* (2006) and related work declared 'unaltered wilderness' to be a fallacy in an age of global change, which we now call 'the anthropocene'*.

This flawed statement of motivation leads me to great frustration when I read Kim's overplayed case for agriculture as an apparently reckless source of contaminants applied to the New Zealand landscape, and with implied potential to enter freshwater. The tone espouses 'big "T" truth', yet I find Kim surprisingly selective and often misleading in choosing what 'truth' to present. There is much that can be stated, since the toxic passengers arriving with superphosphate fertiliser carry a lot of baggage, which is messy to unpack. I was perturbed most by Kim's strong focus on radioactivity associated with superphosphate's uranium load, opposing widely accepted understanding that the primary risk is toxicity, and concerns that highlighting radioactivity heightens public confusion (Schipper *et al*. 2011).

Similarly, I can't avoid feeling Kim is deceptive in describing the work associated with the greatest toxic passenger included in superphosphate fertilisers, cadmium. The narrative sidesteps recognition that the fertiliser industry has taken steps to manage the issue historically through voluntary concentration limits, and New Zealand has an action plan agreed by industry and regulators (Cavanagh *et al*. 2013). There is no doubt cadmium remains a serious problem, but we can't evaluate how far New Zealand is from 'solving' our perceived pollution crisis without understanding steps already taken or underway.

There are further concerns about the factual narrative around contamination of our soils, but my overall concern is that finger-pointing seemingly distracts from the path to solving problems, particularly when both facts and motivations remain needlessly in dispute. So, can the book succeed regardless of its weaker chapters? If signalling paths toward possible solutions is enough, some chapters more than meet this test. Two in particular are notable for finding a future where freshwater and farming can co-exist.

In the first, Paul Tapsell and Alison Dewes provide a well-framed case for 'one health' frameworks as a common-sense way forward, delivering healthy land, healthy water, and healthy food. Perhaps more importantly, the concept is even more compelling when shifted from western science and logic into the concepts of te ao Māori (the Māori worldview). My favourite passage in this chapter describes the need to restore mauri (balance in the forces of life) where agricultural growth agendas from governments spanning 2006–2016 overshot environmental limits. This happened in specific places, and so the solution can be framed in a challenging yet targeted way: "Stressed farmers will need leadership and exemplars of lower-footprint farming to transition towards."

In the second, Steve Carden, the CEO of Pāmu (the rebranded Landcorp, which is a transliteration of 'farm') lays out what New Zealand's largest farmer has done to tackle an interrelated shift towards 'farming sustainably and shifting [their] business model.' With both scale and reputation to consider, partly as a state-owned enterprise, Pāmu has actively made itself a leader in many decisions that could look simple in hindsight, from ending the use

*The author uses 'anthropocene with a small 'a' to draw analogy to a 'Period' of geologic time in which humans dominate earth system processes, without focus on when any such Period, denoted by 'Anthropocene' with a big 'A', has begun.

of palm kernel (which is often linked to deforestation in Southeast Asia) to targeting sustainable, market-driven innovation at significant scales, ranging from avocados to sheep-milking.

I recommend other chapters as well worth reading, despite feeling that they didn't create a whole greater than the sum of the parts. Tina Ngata's 'Wai Māori' chapter puts the rest of the book in an essential context, and is a must-read for anyone with limited or piecemeal knowledge of Māori perspectives on water. One notable, but perhaps heavier, read is Catherine Knight's chapter on politics and governance, defining what we perceive in political banter *versus* the nuts and bolts of the Resource Management Act (RMA). For instance, she highlights the hope resulting from the Environmental Defence Society's victory in the 'King Salmon' decision, implying that the resource protection and stewardship/kaitiaki provisions in sections 6 and 7 of the RMA are objectives directly linked to the purpose of the Act, and should not be subject to cost-benefit trade-offs.

Ultimately, when I take a page-by-page or chapter-by-chapter view on whether the book delivers solutions, I feel perhaps there are more marked 'no' than 'yes'. Yet, those marked 'no' do extend Joy's earlier book, *Polluted Inheritance* (Joy 2015), in defining the scope of the problem. On this front, I'd first express disappointment that food health and water storage chapters don't feel better integrated with the solutions I note above. I particularly struggle with closing the book on a chapter "reimagining" landscapes when Tapsell, Dewes and Carden had me convinced there is much we can do to make our current farms more sustainable and more profitable with the right mindset and innovations. Wholesale landscape change may be a solution, but any realist has to worry that it is an abstract one that takes at least a generation or two.

To my mind, the book would be more successful with the stated goal of 'solving' our crisis if Joy had finished with a 'Conclusion' knitting together a path forward, rather than an 'Afterword'. Yet, Joy's Afterword is useful in stating reasons why we seem prone to failure. For instance, consider the dangers in a polarised arena of too much analysis that "cannot see outside its own analytical bubble". That alone is good cause for me to firmly recommend the book if you want to explore the topic from a range of perspectives, and particularly if you might want to get involved in searching for and testing out solutions that could some day be part of a conclusion explaining how we solved this crisis.

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Abstract

The Utilisation of Social Science Research in Policy Development and Program Review*

The aim of this project was to examine research utilisation within public sector agencies in Australia at both state and national levels, focusing on agencies whose responsibilities include human services policies and programs. This project was concerned with examining the processes, practices and circumstances that facilitate and hinder the uptake of academic social research within policy and program contexts.

The project was supported by an Australian Research Council (ARC) grant and undertaken in conjunction with nine public sector industry partners. The project involved both surveys and interviews with academic researchers and staff of public sector age.

Results suggest that the current processes, practices and circumstances of both academic researchers and policy-makers inhibit the translation and uptake of academic research within public sector policy contexts. Public sector agencies and academic institutions have very different cultures, incentives and expertise. Both policy staff and researchers attest to the need for better processes for research translation and interaction. Agencies may need to be encouraged to build networks with academic researchers; while academic researchers should heed the preferences of policy-makers, by providing summary documents, translating research findings into policy relevant results, and generally transmitting research into formats that facilitate policy uptake.

*ARC Linkage Project Report, Institute of Social Sciences Research (ISSR), University of Queensland,
Project co-leaders: Professor Brian Head, Dr Adrian Cherney, Professor Paul Boreham
https://issr.uq.edu.au/files/2893/EBP%20Project%20Summary%20Report.pdf

Other ISSR 'Bridging the Research Policy Divide' projects can be found at: http://www.issr.uq.edu.au/EBP-Publications

News

Current land-based farming systems research and future challenges

The Ministry of Business, Innovation and Employment (MBIE) has released a report by Sapere Research Group identifying global trends likely to affect the future of food and farming, and the implications for New Zealand's science and innovation system.

The report identified three international trends:

1. Enhanced environmental consciousness: Global consumers are increasingly demanding products that fulfil a growing range of environmental demands.
2. New technological developments and transformational science: These developments include advances in the science of genomics, plant-based proteins and cellular agriculture.
3. Changing consumer preferences and other trends: In addition to environmental and animal welfare concerns, consumers will continue to raise demand for quality, food safety, health benefits, provenance, ethics, and biosecurity.

MBIE commissioned this report to better understand the role of science and innovation in responding to potentially disruptive and transformative changes in agriculture and food production.

The full report can be viewed at: https://www.mbie.govt.nz/about/news/future-farming/

News

The 2018 Prime Minister's Science Prizes

The Prizes, now celebrating their tenth year, recognise the impact of science on New Zealanders' lives, celebrate the achievements of current scientists and encourage scientists of the future. The year's awards are presented early in the following year.

Jim Renwick, past NZAS president (2009–2011) and Professor and Head of School of Geography, Environment and Earth Sciences at Victoria University of Wellington has won ***the 2018 Prime Minister's Science Media Communication Prize***.

In the past five years, Jim has been involved in more than 100 public presentations about climate change, given more than 200 media interviews in New Zealand and internationally, and presented at numerous conferences focused on climate change and how to mitigate its effects. He says he feels a sense of duty to tell the world about the science behind climate change, the consequences that are unfolding, and the urgent need for action. He will use the prize funds to build collaborations on climate change between artists and scientists and to further strengthen links with tangata whenua.

Prime Minister's Science Prize: The premier award of the Prime Minister's Science Prizes has been awarded to the STRmix™ team, from the Institute of Environmental Science and Research (ESR). The STRmix™ software interprets DNA material from multiple individuals at a crime scene, and has been used in more than 100,000 cases worldwide.

Prime Minister's MacDiarmid Emerging Scientist Prize: Awarded to outstanding emerging scientist, Dr Peng Du from the Auckland Bioengineering Institute at the University of Auckland. Dr Du's world-leading research helps the diagnosis and treatment of gut problems.

Prime Minister's Science Teacher Prize: Carol Brieseman from Hampton Hill School in Tawa, Wellington, has been awarded the prize for her work to inspire students, teachers, and communities. As well as encouraging her students to ask difficult questions, Ms Brieseman supports and mentors other teachers, and prompts science initiatives across the school.

Prime Minister's Future Scientist Prize: Awarded to Finnegan Messerli, a former student at Onslow College, Wellington. Finn's research into the physics problem, why grains of salt form a cone-like pile when poured, will ultimately help scientists better understand the risks of avalanches and slips.

More information on the Awards and their recipients can be found at:

https://royalsociety.org.nz/news/2018-prime-ministers-science-prizes-presented/

News

The 2019 World Science Forum, 20–23 November in Budapest, Hungary

The 2019 World Science Forum, which takes place in Budapest, Hungary, between the 20 and 23 of November, will provide an opportunity for the considerations of scientists, policy-makers, society, industry and science communicators to be challenged from an ethical standpoint in the plenary sessions, and will also allow for more technical debates over issues of science in thematic sessions.

The first UNESCO World Conference on Science was held in 1999 in Budapest. Since 2003 the Forum has played a prominent role in bringing leaders of the world of science and policy together. The biennial Forum aims to discuss the roles, responsibilities and challenges of science and present issues of common interest to the scientific community and the general public.

Partner organisations of the World Science Forum are the: United Nations Educational Scientific and Cultural Organisation (UNESCO); International Science Council (ISC); American Association for the Advancement of Science; the InterAcademy Partnership (IAP); World Academy of Sciences (TWAS); European Academies Science Advisory Council (EASAC); and Hungarian Academy of Sciences as the initiator of the host of the 2019 Forum.

Further information can be obtained at: https://council.science/

scientists.org.nz
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27 March 2019

An Open Letter of Support from the NZ Association of Scientists to science colleagues and their families affected by the Christchurch mosques terror attack

As-Salaam-Alaikum
Kia tau te Rangimarie
May Peace Be Upon You

Kia ora e hoa mā,

Like the rest of the country, the New Zealand Association of Scientists is devastated by the Christchurch mosques terror attack. At this time, we want to wrap our Muslim whānau – our colleagues and their families working or studying in science, social science, and the humanities – with aroha.

As many of us moved from joyously engaging with direct action promoting climate justice, led by our rangitahi (youth), on the morning of Friday 15 March, to despair as a racist, anti-Islamic act of evil was committed, the best and worst of how people can be was brought into high relief. Our thoughts and support are offered to those who are affected and those who grieve with them.

The relationship between science and religion is often considered to be complex. However, what remains absolutely clear at this time is that all people have a right to their beliefs and to carry them out as part of their community – of our community. On the 15th of March a sector of our community, our whānau, was attacked because of these beliefs. They receive our compassion, support, and understanding.

The science community is an international one – filled with people from all backgrounds. In many cases these people, our science whānau, have travelled great distances with a view to improving the lives of themselves and their families. In doing so, they contribute to science and the science community in any number of ways. The New Zealand Association of Scientists commits, once again, to supporting the aspirations and careers of all scientists in Aotearoa New Zealand, and to speaking up on the issues which clearly affect them.

As an Association, we have a statement of purpose around exposing pseudo-science, debating and influencing government science policy, and improving working conditions for scientists, including gender and ethnic equality. The extent to which these have directly addressed the issues of anti-Islamic sentiments and the so-called 'Alt-Right' is now revealed as inadequate – though they attest to our commitment to speak the truth and expose lies. In the coming weeks and months, we will work with colleagues throughout research and academia in Aotearoa New Zealand, particularly Muslim researchers, to develop resources on and protocols for dealing with the many issues this horrendous terrorist attack raises.

Ngā mihi

Kate Hannah and Craig Stevens on behalf of the NZAS President and Council

Oceania ACES
A Community on Ecosystem Services

OCEANIA ECOSYSTEM SERVICES FORUM 2019

Creating healthy communities and ecosystems for a resilient future

Ōtautahi (Christchurch), Aotearoa New Zealand

2-6 September 2019

The Oceania Ecosystem Services Forum (OESF) aims to bring the best ecosystem services research, practice and knowledge from around the world to the Oceania region; and showcase the best ecosystem services research, practice and knowledge occurring in Oceania to the rest of the world.

This year's OESF provides a platform for participants to interact across different communities and knowledge systems (e.g. academic, indigenous, traditional).

The 2019 Oceania Ecosystem Services Forum (OESF 2019) aims to:

- connect communities, businesses, policy makers and researchers working on ecosystem services and resilient communities
- showcase diverse practices, knowledge (practical, traditional, indigenous, academic) and policies that contribute to increasing the health of communities and their ecosystems, and
- discuss new approaches and actions that diverse ecosystem services teams use to address climate change, biodiversity, and the Sustainable Development Goals

Plenary sessions, workshops and a field trip will offer ways to learn about and discuss the following topics:

- data, assessment and reporting of ecosystem services
- ecosystem services in decision-making processes
- connections between natural capital, ecosystem services and human wellbeing, and
- integration of ecosystem services across landscapes, sectors and disciplines.

If you have any questions or would like to volunteer to OESF 2019 please contact the OESF 2019 Organising Committee (Richard Yao, Sandra Velarde, Tim Payn, Simone Maynard): oceaniaesforum@gmail.com

Join our Community to discuss, workshop, present and brainstorm innovative approaches and state-of-the-art methods to using ecosystem services concepts to address sustainability.

Register at: https://oceaniaesforum.com