Article

Independent scientific research entities in New Zealand: Cawthron Institute as a case study

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The Cawthron Institute in Nelson is used as a case study in the history of the management of science in New Zealand, set against the background of the development of DSIR in the 1920s and the science reforms of the 1980s–1990s. The early scientific and managerial successes of the Cawthron scientific research institute enabled it to build relationships with DSIR, while still remaining committed to the application of the research undertaken to its region. The latter commitment has endured, and so the Institute is able to occupy the middle ground between the 'industrial science' of the Crown research institutes and the 'academic' science of universities, as do some individual scientists as contractors.

Keywords: Cawthron Institute, research, T.H. Easterfield, DSIR, CRIs, science funding

Introduction

The history of science in New Zealand is generally described from the perspective of the 'institutions' of science established by provincial governments (e.g. Otago's Geological Survey) and central government (in particular the Geological Survey and the Colonial Laboratory – see Fig. 1), and the New Zealand Institute, which as well as being a forum for the oral dissemination of research at its meetings, exerted a peer review function in the publication of research. Initial research efforts were oriented to the discovery of the 'new' land's flora and fauna and the understanding of its geology, and were generally undertaken by gentleman scholars with the time and/or financial resources that could be devoted to such pursuits. However, not all would-be researchers found employment with government agencies or their associated bodies, and had to struggle to survive while carving out a scientific career (e.g. Hyde 2016, 2017).

As the actual and potential economic value of the nation's resources became apparent, description of flora, fauna, rocks, minerals and water needed to be complemented by testing and analysis of samples, for which equipment and staff skilled in its use was necessary. In addition, as colonial society became established, manufacturing and the supply of consumer goods brought its own challenges, requiring testing and analysis, to ensure foods were unadulterated and goods were of reasonable quality. In addition there were a few independent laboratories in some larger communities, e.g. that of the chemist William Grayling (Wood 2016), who contracted their services to the Laboratory. A few independent botanists and geologists / conchologists (e.g., Henry Suter: Hyde 2017; Margaret Mestayer: Hayward 2012, Hayward & Morley 2011) also contracted their services – and sometimes donated their 'finds' – to the Colonial Museum or regional geological surveys.

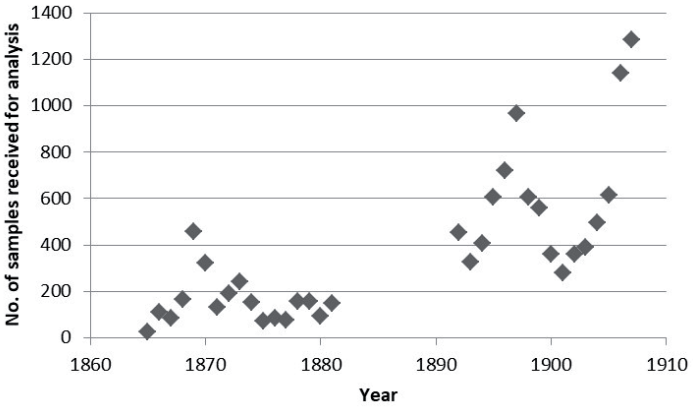

Figure 1. Number of samples sent to the Colonial Laboratory for analysis, 1865–1881, 1892–1907 (Compiled from 'Records of Samples Books' 24994, Archives New Zealand)

In comparison, the privately endowed and operated Cawthron Institute, established in Nelson, was – and has remained – research-focused, and has outlasted Government research institutions with which it has competed and within which it could have been subsumed. From 25 staff-members in 1970, the Institute has grown to more than 220 in 2018 (Reflections…, 2018). This article explores possible reasons for the Institute's

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survival independent from the tentacles of the expansionist Department of Scientific and Industrial Research (DSIR), and from the Crown research institutes into which DSIR's research divisions ultimately morphed.

Establishment and early development of the Cawthron Institute

The Cawthron Institute was established in 1920 in Nelson (New Zealand) as a result of the Supreme Court approving the recommendations made by the trustees of the estate of Thomas Cawthron 'who bequeathed practically the whole of his estate valued at £240,000 for the establishment of a Technical Institute and Museum' upon his death in 1915 (*Silver Jubilee of Cawthron Institute* 1945). The recommendations were formulated for the trustees by a commission (Table 1) comprising five eminent scientists of the time who spanned the disciplines of science and were drawn from across the country, under the chairmanship of Sir James Wilson.

The Commission's report, prepared by Professor Easterfield proposed 'That the chief scope of the work of the Institute should be instruction in and performance of scientific research…. Such research to be definitely related to the industries of Nelson, and of the Dominion', noting 'That inasmuch as agriculture is and is likely to remain for many years the most important industry both of Nelson and of the Dominion, the research work should in the first instance bear chiefly upon this industry and in particular upon fruitgrowing' (Miller 1963: 81).

Although the Commission's report was parochial, it was not myopic in its view of research, adding 'That provision should … be made, as funds permit, for systematic research on other subjects, e.g. the chemistry, physics and biology of the soils, the development of forest lands, including re-afforestation, the utilisation of clays and other minerals, the fish industry and such other subjects as may from time to time be deemed important and worthy of study' (Miller 1963: 82). As discussed later, this potential diversity of research matched well with that which was subsequently both proposed and implemented by the government research agency – the Department of Scientific and Research – in the late 1920s.

Little appears to have been made of the Commission's recommendation that the Institute should have an educational function, viz. 'It would be an Industrial and Technical School in the true sense of the word, *teaching* [italics added] effectively the application of science to our national industries', possibly because it is overshadowed by that particular recommendation's closing sentence which makes a plea for *research* funding. Had teaching been provided in an 'industrial and technical school' within the Institute as recommended, it would certainly have aligned at least with Easterfield's own largely New Zealand-oriented applied research activities undertaken while at Victoria University College (Halton 2012, p. 152-153), shown in Figure 2.

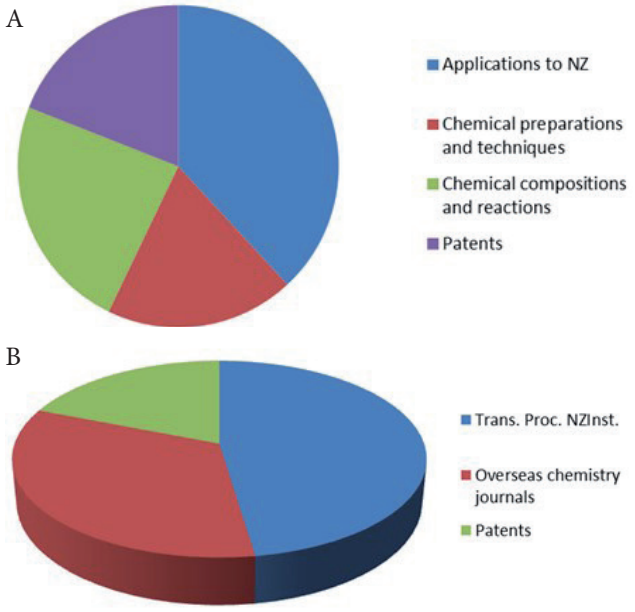

Figure 2. Distribution of the 21 research outputs of Professor T.H. Easterfield, while at Victoria University College, 1900–1915.

A: by topic – applied chemistry, 'pure' chemistry and patents.

B: by type of publication – ***Transactions and Proceedings of the New Zealand Institute*****, overseas chemistry journals, patents.**

Curiously, had a site for Victoria University College not been found in Wellington, Easterfield might have been a chemistry professor of a Nelson-based educational institute. A footnote to the history of the Cawthron Institute (Miller 1963: 95) refers to a resolution carried by the colony's Legislative Council in 1900 that 'failing the choice of a site in Wellington, the Victoria College Act be amended to enable a site being selected in Nelson', as reported in the *Colonist* newspaper (*Colonist*, 29 September 1900). This proposal 'led to a lively controversy' before it was rescinded (*Colonist*, 10 October 1900). It is possible to imagine the distinctive first building of Victoria College (Figure 3A) being built on one of the hills surrounding Nelson – perhaps those same hills that were considered as sites for a proposed solar observatory to be funded by Cawthron (Proctor 1914), or possibly his own preference, Britannia Heights. Equally possible is that the conversion of space in 'Fellworth' (Figure 3B), the house initially purchased as the headquarters of the Cawthron Institute, could have accommodated university teaching laboratories similar to those portrayed for chemistry teaching at Victoria University College (Figure 3C).

Easterfield was offered the appointment as the first director of the Cawthron Institute in October 1919, and accepted it the following month, albeit with 'diffidence' (Easterfield, 1933). His appointment is unsurprising, given his authorship of the Commission's report and his undoubted commitment to research. This commitment was articulated in his Victoria University

Table 1. Members of the Commission to advise the trustees of the Cawthron estate.

Commission member	Discipline	Role	Location
Chair: Sir James Wilson	Agriculture	President of the Board of Agriculture	Bulls (Manawatu)
Professor T.H. Easterfield	Chemistry	Professor of Chemistry (and Physics until 1909)	Victoria University College, Wellington
Professor W.B. Benham	Biology	Professor of Biology	Otago University, Dunedin
Professor F.P. Worley	Chemistry	Professor of Chemistry	Auckland University College, Auckland
Dr P. Marshall	Geology	Professor of Geology and Mineralogy	Otago University, Dunedin
Dr L. Cockayne	Botany	Independent researcher	Wellington

Figure 3. What might have been.

A (left): The original building for Victoria College (Victoria University College after 1914) on the Kelburn hillside overlooking Wellington city, 1918 [Image: Alexander Turnbull Library, Ref.: 1/4-023178-G].

B (centre): 'Fellworth', Cawthron Institute's home in Nelson [Image: Easterfield, 1933, facing p. 4].

C (right): 'Victoria College: First Chemistry Laboratory 1901' by Sybil Johnson – a watercolour of the laboratory in the Wellington Technical College, Victoria Street [Image: https://teara.govt.nz/en/artwork/43356/victoria-colleges-first-chemistry-laboratory-1901].

College inaugural lecture (1899): 'Research as the prime factor in a scientific education' (Easterfield 1949). Barrowman (1999: 16) noted that in this lecture Easterfield 'argued for early specialization by students, research and original investigation as a significant component of undergraduate work and the "absolute necessity" of a "really good laboratory"'. At Victoria, Easterfield is said to have 'inspired a group of young research students, most notably his eventual successor, P.W. Robertson', and while at Cawthron he similarly 'trained and inspired a group of scientists, one of whom succeeded him when he retired from the directorship in 1933' (Davis 1996).

Consistent with the Commission's recommendations, Easterfield oversaw the Institute's research development in three main areas: (a) agriculture and chemistry, (b) mycology, and (c) entomology (Rigg 1945). Figure 4 shows that for the first 25 years of the Institute's existence research in these three themes was – at least initially – Nelson-centric. Even in later years, these themes remained dominated by research considered to be relevant to New Zealand.

From the outset, the Institute sought and obtained financial support from the primary industries which benefited directly from its research, the Department of Agriculture and Britain's Empire Marketing Board. This approach to funding pre-empted the development of the research associations established years later under the auspices of the Department of Scientific and Industrial Research.

With his applied research interests, it is interesting to speculate that had Easterfield stayed at Victoria University College and had Sir Robert Stout achieved his vision of linking university scientific research with that of Government to form a single 'large scientific university in Wellington', the organisation of scientific research in New Zealand could have been very different, resembling the idea that Stout (1920) advocated:

> *… a large scientific institute or University college situated in Wellington that could have done all the research work and technical work required by the various Government Departments , and which at the same time should have been a teaching institution. Some aid could have been got from students doing research work when they were not engaged in their studies during the University session, and the whole of the scientific*

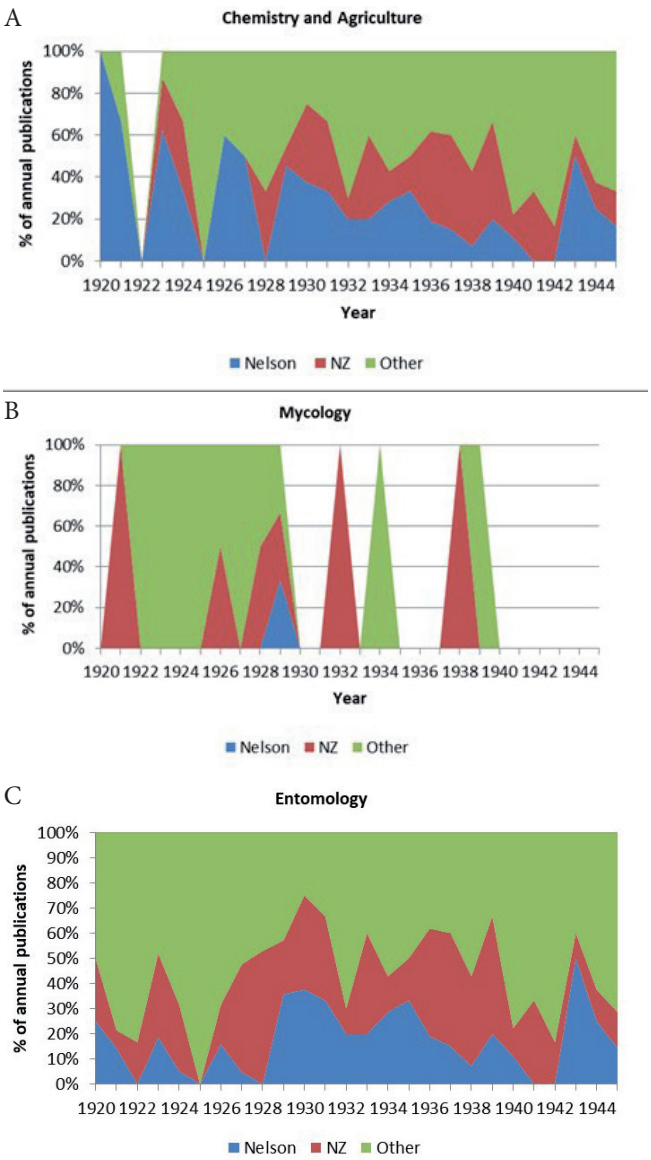

Figure 4. Variation of publications of the Cawthron Institute whose titles indicate application to Nelson or New Zealand, for the three initial research themes of the Institute, 1920–1945 (compiled from Rigg 1945, pp. 38–50). A: Chemistry and Agriculture; B: Mycology; C: Entomology.

work of the colony [sic] could have been more co-ordinated than it is now.… The establishment of such an institution would not interfere with scientific work for University colleges, but it would be an economical gain to the Government were there one large Science University in Wellington…

This idea was explored with reference to the Cawthron Institute in an editorial of the then recently established *NZ Journal of Science and Technology* (Anon 1920) noting that:

… the Cawthron Trustees do not regard the bequest as a local affair. Though the home of the Institute will be in Nelson, its interests will be nation-wide. They consider that the whole Dominion and the Empire should benefit by the researches carried out in the Institute and the principles established there. They recognise also that there is no line of demarcation between pure and applied science, and that the pursuit of the two should go hand in hand if results of great economic value are to be obtained.

The editorial also drew attention to the possibility that bequests and donations from other sources could be used for buildings and also new scientific departments, scholarships and fellowships, and endowments for the library and museum.

Cawthron Institute and the embryonic DSIR

The focus on applied research by Cawthron staff, the Institute's modest success in attracting funding from primary industry interests (Miller 1963: 64–87) and the co-operation with existing government scientific agencies – in particular, the Department of Agriculture (Table 2), should have resonated with Sir Frank Heath, the proponent of the establishment of a new government agency (largely mirroring Britain's Department of Scientific and Industrial Research), the purpose of which was 'to co-ordinate and support research carried out in existing institutes or in new research associations formed in co-operation with particular industries' (Galbreath 1998: 18).

Heath's visit to New Zealand in early 1926 involved his looking at current research activities and, through discussion with leaders of primary and secondary industries, assessing future research needs. As part of Heath's extensive itinerary throughout New Zealand, he visited Nelson and the Cawthron Institute (Figure 5A).

Of the visit, the *Evening Post* (23 February 1926) reported, 'He [Sir Frank Heath] was deeply impressed with the work being done by the Cawthron Institute. New Zealand was getting its "full whack" out of that institute. The work done on woolly aphis alone was worthwhile. It is a very good example of what sound

A

B

Figure 5. Exploring a new direction for New Zealand's scientific research. A (top): Sir Frank Heath (at left) with Sir Thomas Easterfield (Director of the Cawthron Institute), February 1926 [Image: Alexander Turnbull Library, Ref.: PA Coll-5584-50]; B (below): The Assistant Director of Education, Dr Ernest Marsden (at left) who accompanied Sir Frank Heath (at right) and Lady Heath on the North Island part of their New Zealand tour [Image: ***Auckland Star*****, 5 February 1926].**

scientific research can do.' This suggests that Heath had been made aware of the six research publications relating to woolly aphis written by the Institute's Chief Biologist and Entomologist, R.J. Tillyard, between 1921 and 1925, described subsequently in Noyes & Valentine (1989). The newspaper reported that Heath had said of the Institute, 'It is a fine place with a fine staff. I would like to see it twice as strong…' Despite the Cawthron Institute making a favourable impression on Heath, his report did not advocate any change in the institute's standing or role, either

Table 2. Co-operation between Cawthron Institute and Department of Agriculture staff prior to DSIR's founding in 1926.*

Cawthron Institute*		Department of Agriculture†	
Research theme	Key staff	Key staff	Research theme
Soils and agriculture	Theodore Rigg	B.C. Aston	Soils
	(assisted by M.W. Young and	A.H. Cockayne	Pastures
	E.J. Champteloup)	J.A. Gilruth	Veterinary
Mycology	Dr Kathleen Curtis	G.H. Cunningham	Mycology
		T.W. Kirk	Fruit
Entomology	R.J. Tillyard	D Miller‡	Entomology
	(assisted by A.Philpott and D.D. Milligan)		

* 1920 staff listed in *Silver Jubilee of the Cawthron Institute 1920–1945*, 29 October 1945, p. 11.

† Compiled from text in Miller 1963: 96.

‡ Miller subsequently became the Director of DSIR's Entomology Division, as well as holding a role at Cawthron (see text).

regionally or nationally. Rather, he envisaged that the existing Dominion Laboratory was to be the nucleus of a department to advise the Government and manufacturers on various problems connected with industry and to form a centre for the special scientific investigations required.

Media commentators seem not to have noticed that the two government officials who accompanied Heath on his tour of New Zealand fared well in the administrative structure proposed by Heath and subsequently agreed to by the Government: the then Assistant Director of Education Dr Ernest Marsden (who accompanied Heath in the North Island, see Figure 5B), was appointed as the first Permanent Secretary of the Department of Scientific and Industrial Research; and Dr J.S. Maclaurin (who accompanied Heath in the South Island) was already the Director of the Dominion Laboratory, which was to be the 'nucleus' of the new department.

Heath's report also identified the need for an agricultural college in a dairying region, which would ultimately be established on the outskirts of Palmerston North. If it had not been for the insistent requirement for the proposed college to service the dairying industry, the Cawthron Institute might have been a good choice for an agricultural college, given the range of research into primary production already carried out there, and the diversity of soil types in its surrounding countryside (Figure 6). Moreover, such a college would have realised the educational aspirations of the Institute's founders.

Incidentally, Cawthron's being a national science research institute was not the only opportunity for national prominence that Nelson was denied: Nelson could have been New Zealand's capital city. Given the intense parochialism in colonial New Zealand, moving the capital city from Auckland to a location closer to the country's geographic centre was never going to be an easy decision (Brett 2016: 158–159). The matter was resolved in 1863 by accepting the recommendation of an independent commission which after consideration of six 'capabilities' (accessibility, water – specifically harbour, land, resources, defence, and natural disadvantages) decided on Wellington rather than Nelson (*AJHR* 1864).

Although Easterfield was not a member of the Cawthron Institute Trust Board, his thinking and ideas were clearly well matched to the Board's aspirations, as is apparent by his writing the Commission's report. In effect, his and the Trust Board's entrepreneurial orientation appear to have been well matched (Miller & Breton-Miller 2011), although whether that orientation extended to an ambition for the Cawthron to be a national research institution is less clear. Certainly Easterfield's successor as director Theodore (later Sir Theodore) Rigg – who had initiated the Waimea County Soil Survey (see Figure 6) – appears not to have had any such ambition, perhaps because of the precarious nature of research funding through the Depression years, but perhaps also because of an inferred 'demand for security and resources limited their EO [entrepreneurial orientation] and constrained performance', considered to be a likely occurrence in small public entities (Miller & Breton-Miller 2011).

Cawthron's Theodore Rigg was invited by DSIR in 1930 to direct its survey of the North Island soils derived from volcanic ash (now often referred to as 'tephra'). DSIR staff conducted the field surveys while the analytical work was undertaken by E.B. Kidson 'who was seconded to the [Cawthron] Institute to assist in the analyses of the countless soil samples' (Miller 1963:

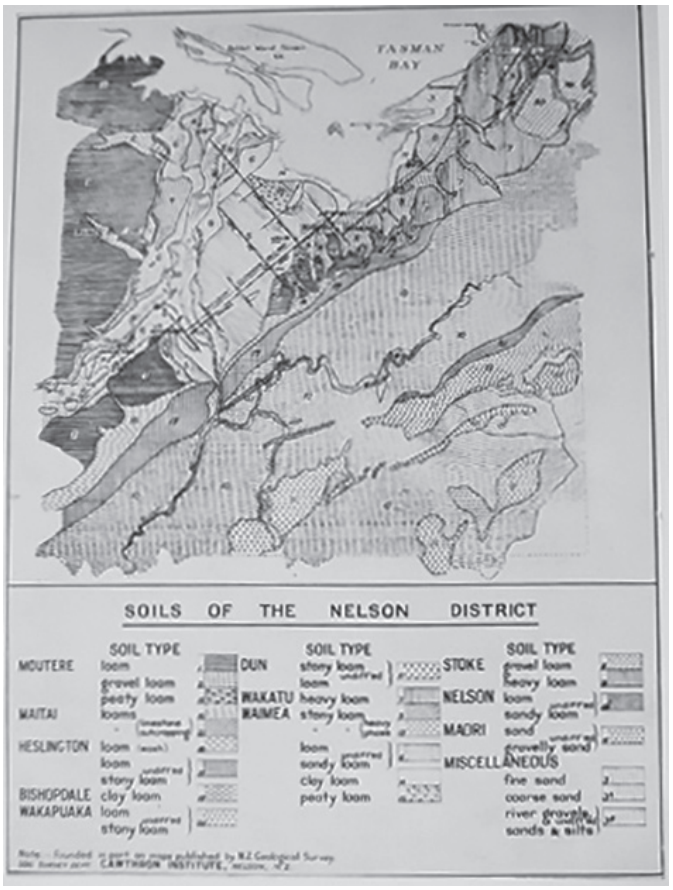

Figure 6. The Cawthron Institute undertook the first systematic soil survey in New Zealand, from which a soil map of the Waimea Plains was drawn. The map identified 23 different soil types and reflects the complexity of the underlying geology [Image: Rigg, 1945, facing page 4].

118). A reason for Cawthron undertaking this work may have been because of the few changes that had been made to the Dominion Laboratory's facilities during the 1930s, and because of the Laboratory's prime commitment to meeting the needs of other Government departments (Hughson & Ellis 1981: 66, 70–78). However, Cawthron's involvement had the unexpected advantage of enabling the recognition of the similarity of the 'bush-sickness' associated with animals grazing the tephra-derived soils of the North Island to the animal sickness noticed at Glenhope in Nelson and Morton Mains in Southland, areas with which the scientists at Cawthron were already familiar (Rigg & Askew 1936a, 1936b), and which led to the identification of cobalt as the elemental deficiency in all these soils (Askew & Dixon 1936, Dixon 1936). Much later the economic benefits of the research carried out into bush sickness was lauded by Clare (1999) as having been 'huge', and the most commonly cited justification of the expenditure of public funds on research.

Of these developments Miller (1963: 119) comments, 'So it came about that the initial surveys carried out by Rigg in Nelson, together with those of the Research Department under his direction elsewhere, fathered the national soil service.' Rigg's 'fathering' would seem to have provided an opportunity for the Cawthron to become a national research organisation, particularly once, as Robertson (1998) observes, he had become

> *… a leading figure in all aspects of agricultural research. He became head of the Department of Agriculture and Chemistry in 1924 and assistant director in 1928, and in 1933 (on the*

retirement of Easterfield) director of the Cawthron Institute. In the early 1930s he was director of the soil reconnaissance survey of the central North Island, and from the mid 1930s he was for nine years officer for the Soil Survey Division in charge of chemical work for the DSIR. He [Rigg] was a founding member of the Council of Scientific and Industrial Research from 1926 to 1954, and became its chairman from 1943. From 1926 he was associated with the foundation and administration of many committees of the council, as well as other organisations concerned with science in agriculture. He was a member of the Nelson Catchment Board from its inception in 1944 and chairman from 1950 to 1956, a member of the New Zealand Advisory Section of the Nuffield Foundation (1946–58), and chairman of the Farm Committee. On two major trips overseas he attended delegations representing New Zealand: in 1927, at an international soil conference in Washington DC, and in 1946 at the Imperial Agricultural Bureaux Conference, London.

Helen Hughes, the daughter of Theodore Rigg, noted that a former staff member considered that her father 'missed an opportunity to build an empire while he had influence as Chair of the Scientific Research Council; instead, he let DSIR establish the Appleby Research Station, and the Tobacco and Hop Research Stations' (Hughes 2005: 74). However, she countered this somewhat in the next paragraph by saying: 'However, a former DSIR scientist, who as a young man took notes at Council meetings, recalls my father picking up work for Cawthron at every available opportunity. Although Cawthron did not own the Research Stations, nevertheless they carried out a great deal of analytical and mycological work for them.' Hughes considered that Rigg 'built up an excellent *esprit de corps* among the staff of the Institute which enabled the joint attack which so many problems at that time required if success in their solution and adaptation into practice was to be attained'. With such a small staff, the esprit de corps referred to by Hughes may have given Cawthron something of the atmosphere of a 'family firm', for which collaboration with other research entities appears to have been considered by Rigg to be more desirable than either competition with DSIR or amalgamation with that entity.

Rigg retired from the directorship in 1956, and subsequently married the Institute's long-time leader of mycology research – Dr Kathleen Curtis (Royal Society of NZ 2017a), who had retired in 1952. Had this marriage occurred earlier, this might have imbued the Institute with even more of the character of a 'family firm', which recent research into management culture might have been seen as beneficial (Mehrotra *et al.* 2011). Rigg's successor as director from 1956 – David Miller – does not appear to have harboured expansionist ambitions for the Institute either, Miller (1963: 98) commenting:

A natural outcome in the progress of any healthy institution engaged in several fields of research is that certain phases of the work tend to assume a magnitude too great for an institution – especially one of limited resources – to carry further, and they become functions of major specialized organisations engaged on such phases. So it has been with the Cawthron Institute, which originally tilled many fields and developed certain phases of agricultural research to a stage where they were taken over as branches of the Department of Scientific and Industrial Research. As a result of that, the Institute, no longer standing alone but retaining the autonomy of a privately

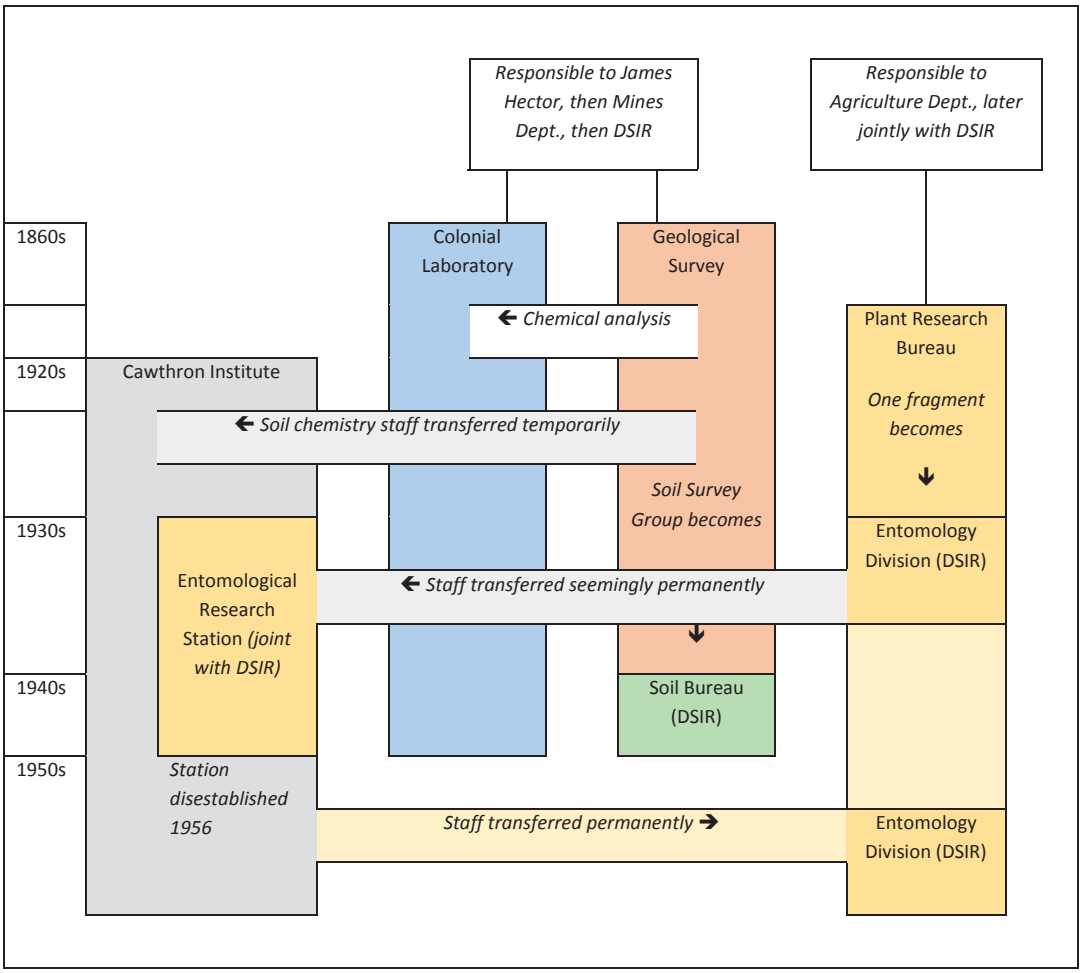

Figure 7. 'Comings and goings': linkages between Cawthron Institute and Government research agencies.

endowed institution, has become a part within the overall framework of agricultural research in New Zealand. To meet that changing scene, the Institute entered a new era and was reorganized during 1956 to 1959 to deal mainly with problems of plant and animal nutrition in the Nelson district.

This re-organisation – which by today's terminology would probably be considered a 'return to core business' if not an outright retrenchment – was undertaken during Miller's directorship of the Institute from 1956 to 1959 (he having served more than the previous two decades as Assistant Director). The sentiments Miller expresses in the paragraph above also need to be assessed in the context of his own appointments: during the time Miller was Assistant Director of the Cawthron Institute and was its Chief Entomologist he headed – from 1949 – a joint DSIR–Cawthron Nelson-based entity known as the Entomological Research Station. When Miller was appointed as Cawthron's director in 1956, Entomology Division was separated from Cawthron as a 'regular' division of DSIR (Galbreath 1998: 238). Although Miller may not have envisaged such a possibility, Entomology Division was transferred in 1973 to Mount Albert in Auckland to rejoin Plant Diseases Division from which it had separated in 1936 (Galbreath 1998: 101–102, 258), and a decades-long association between the Cawthron Institute and various divisions of DSIR effectively came to an end (Figure 7, *see* p. 8).

In an approach akin to that which purports to bring human activity into the ambit of science (Watson 2016: 452), Miller's (1963) history of the Cawthron Institute to the early 1960s can be represented as the 'anticipation', 'dream' and 'frustration' stages that characterise many works of fiction (Table 3), particularly the 'Rags to Riches' type of plot (Booker 2004: 563–566). However, the ultimate 'riches' – a prominent national role for the research institute, which may have been envisaged by Cawthron, and possibly by Easterfield – are unlikely ever to be achieved, despite the dissolution of DSIR providing the tantalising prospect of such a role.

Coping with competition

The 1980s were turbulent times for New Zealand: the initiation of an 'open economy' and reliance on the 'market' to determine the provision and cost of services was far-reaching, and led to the 'dismantling of DSIR', and the subsequent rearrangement of some of its research divisions into new entities in 1990 and later – in 1992 – re-forming them as parts of several new entities: the quaintly named thematically focused Crown research institutes (CRIs) listed in Table 4 (Galbreath 1998: 256–264). Some of these Institutes also included the research entities of other government departments (e.g. that within the Department of Agriculture which became AgResearch) and agencies (e.g. NWASCO – National Water and Soil Conservation Organisation, which became part of NIWA). Not all CRIs survived: an early casualty was the Institute for Social Research and Development; and the years since 1992 have seen a reduction in their number from ten to seven, as well as some repurposing and rebranding.

The formation of these Institutes occurred with significant redundancy of scientific and support staff. As noted by Pockley (1996):

… many scientists have been disillusioned by the impact of a thirty percent decline in government funding [of science] since 1981… A survey of the 300 members of the Association [New Zealand Association of Scientists] in the academic community, government and industry found that the scientific workforce had been 'traumatised and decimated' and its productivity 'greatly reduced'.

That disillusionment would be a consequence of the reforms is readily apparent when a comparison is made between 'academic science' (undertaken by universities), 'state science' (undertaken by DSIR) and 'industrial science' (undertaken by CRIs and research associations), as described by Charlesworth *et al* (1989: 223–224) and shown in Table 5.

Table 3. Interpretation of events in the history of the Cawthron Institute with the stages of fictional plots.

Fictional Plot ↓	**Stage ❶**	**Stage ❷**	**Stage ❸**	**Stage ❹**	**Stage ❺**
Overcoming the monster	Anticipation and 'call'	Dream	Frustration	Nightmare	Thrilling escape and death of monster
The quest	The call	The journey	Arrival and frustration	The final ordeals	The goal
Voyage and return	Anticipation and 'fall' into other world	Initial fascination or dream	Frustration	Nightmare (survival threatened)	Thrilling escape and return
Comedy	Shadows of confusion, uncertainty and frustration		Confusion and darkness, leading to a nightmarish tangle		Shadows dispelled, miraculous transformation; reunion
Tragedy	Anticipation	Dream	Frustration	Nightmare	Destruction
Rebirth	Hero or heroine under shadow of dark power	All goes reason-ably well, threat may recede	Threat returns, hero or heroine imprisoned in living death	'living death' continues; dark power seems to have triumphed	'miraculous redemption' or Sense of self-fulfillment
Rags to riches	*Initial wretchedness 'The Call"*	*Out in the world, initial success*	*Central crisis*	*Independence and the final ordeal*	*Final union, completion and fulfilment*
History ↓					
Cawthron Institute	*Establishment and report of Commission to trustees*	*Initial success, under Easterfield's directorship*	*Success, but over-shadowed by DSIR's establishment and growth*	*Uncertainty associated with changes to research environment*	*Adjustment to changed research environment*

Table 4. The fate of DSIR's divisions: their distribution across the Crown research institutes.*

Field of research*	Crown research institutes†							Other‡		
	①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩
Antarctic Research									❶	
Applied Biochemistry	●					●				
Applied Mathematics										
Botany				●						
Chemistry		●	●					●		
Crop Research						●				
Ecology				●						
Entomology	●			●		●				
Geology and Geophysics			●							
Grasslands	●									
Horticulture and processing						●				
Industrial Development *and* Industrial Processing								●		
Information and Publishing										❶
Meteorology									❷	
Nuclear Sciences			●							
Physics and Engineering								●		
Plant Diseases	●			●		●				
Plant Physiology						●				
Soil Sciences				●						
Water Sciences					●					

*These 'fields' from Galbreath (1998: 256–264) were often the names of the DSIR divisions.

† As at 2018, Crown research institutes (CRIs) are: 1, AgResearch; 2, Institute of Environmental Research (ESR); 3, Institute of Geological and Nuclear Sciences (GNS Science); 4, Landcare Research; 5, National Institute of Water and Atmospheric Research (NIWA); 6, Plant and Food Research; 7, Scion (formerly Forest Research Institute). Forestry research was never part of DSIR, the Forest Research Institute being associated with the NZ Forest Service, itself a component of a succession of ministries and departments until its reconstitution as a CRI.

‡ Other research entities: 8, Callaghan Innovation, a Crown entity which includes a former CRI, viz. Industrial Research Ltd.; 9, Government ministries, departments and agencies: ❶, Initially associated with Ministry of External Relations and Trade, but currently a government agency – NZ Antarctic Research Institute/Antarctica NZ; ❷, Civil Aviation Authority; 10, Non-governmental organisations: ❶, Royal Society of NZ.

Table 5. Some characteristics of 'academic', 'state' and 'industrial' science in New Zealand.

	Academic science	**State science**	**Industrial science**
NZ examples	Universities	DSIR	Research associations, CRIs
Goals	Scientists have freedom to choose their own research projects	Industry goals overlap with traditional goals of academic science	Goals dominated by employer and industry
Functional arrangement	Disciplinary	Largely disciplinary	Goal-directed: often inter- or multidisciplinary
Staff feelings of 'comfort'	High: performance consistent with training	Modest: performance requirements based on training	Low: performance not in accord with the ideals of the discipline in which scientists were trained
Overall system	A collegial system of disciplinary associations, characterised by a commitment to the production of the best possible knowledge as judged by scientific peers	Goal of producing disciplinary scientific knowledge is carried out alongside and may be subordinate to medical, social, or industrial goals	Emphasis on team research to meet medical, social, industrial, or environmental goals

The – albeit variable – interaction of the former DSIR with the Cawthron Institute was effectively halted by the reforms, potentially leaving the Cawthron Institute as a minor player in the resulting competitive research environment. Cawthron was effectively sandwiched between individual scientists operating as sole-traders or small companies and the larger institutions – principally the CRIs (Whitley 1984), all of which appeared to have intruded into the 'industrial space' – see Figure 8. In fact, the Cawthron Institute has become focused on environmental research and on supporting sustainable development in dairying, seafood, and aquaculture. These are industries and activities of increasing importance to the Nelson–Tasman region, and therefore a fitting link to Cawthron's heritage (see also Table 9).

Some of those scientists made redundant responded to Masood's (1997) challenge: 'Do you aim for traditional posts at academic institutions, look for the relatively lucrative pastures of the private sector, or even beat a path into the world of entrepreneurship?' by establishing scientific or technological consul-

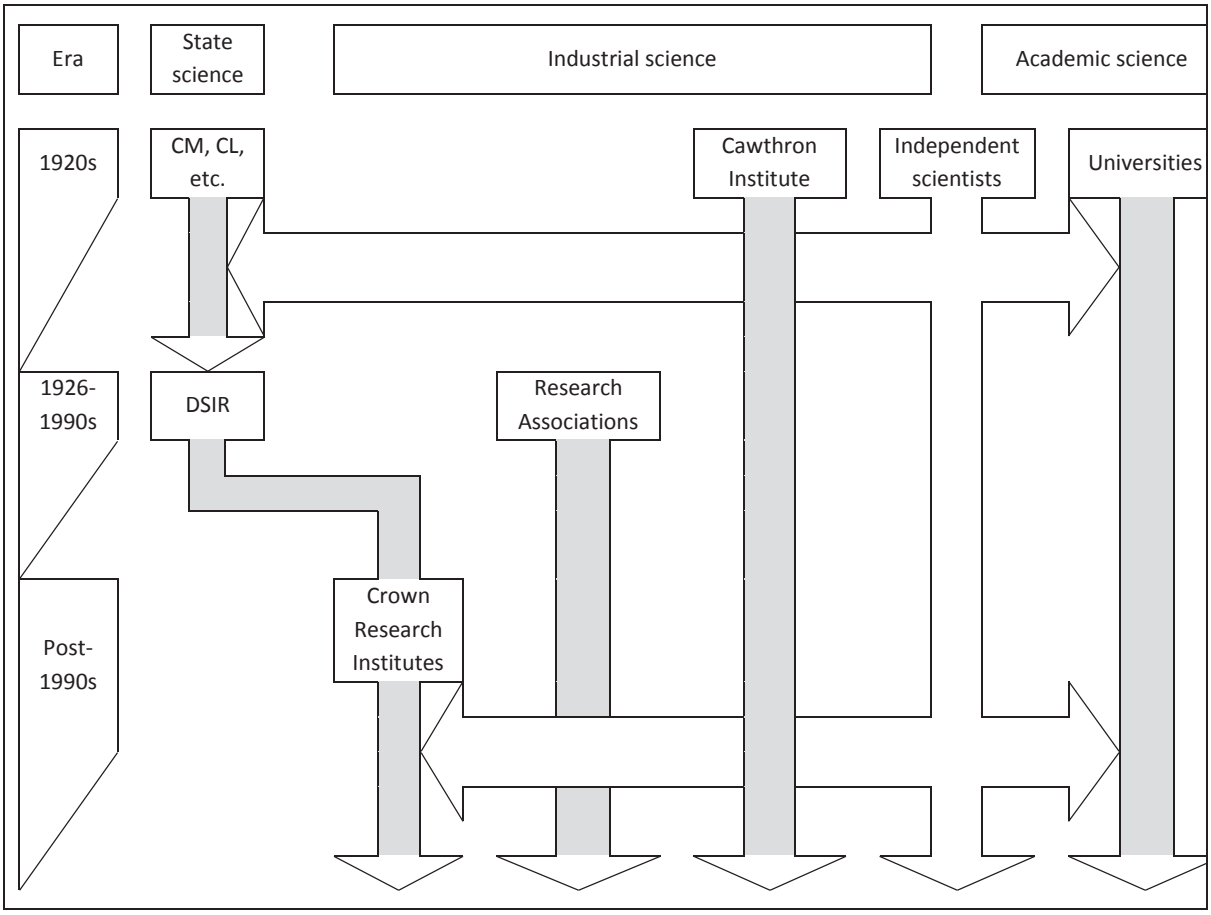

Figure 8. Changes in the organisation of New Zealand science from the 1920s to post-1990s. In colonial times, some independent scientists contracted to universities and state science institutions, especially the Colonial Laboratory (CL), the Colonial Museum (CM) and regional museums, and their associated geological surveys. From the 1990s, independent scientists contracted their services to universities or the CRIs, although some remain independent, seeking funding through other agencies, on occasion including the Marsden Fund.

tancies. These businesses typically operated as sole traders or small companies, sometimes providing scientific services to the CRI into which their former employer had morphed. Lacking the resources generally available to companies formed as commercial spin-offs from universities (Ho *et al.* 2010), businesses of this type that have survived are likely to have remained small.

Table 6 shows that of members of the New Zealand Institute of Chemistry who responded to salary surveys (Boston & van Eyk 2001; Summerfield 2006; Nicholson 2016), the proportion of those privately or self-employed reached a peak in 2006 (39%), and has reduced thereafter, while the proportion of those in the public sector has declined slightly. This suggests that the reforms of the 1990s have permanently changed the structure of the chemical sciences workforce. This inference is probably applicable to other sciences as well.

Despite the rhetoric at the time of the reforms, there appears little evidence that government services (including scientific research) were delivered with greater effectiveness or efficiency as a result of the reforms (Galbreath 1998: 254–255). Rather more likely, the changes are a corporate version of what Booker (2004: 580) describes as an

> *…alternation of illusion and disillusion [that] typifies the pattern of political life even in a peaceful democracy [like New Zealand]. Almost every successful political leader has a 'shelf life', whereby initially he or she commands respect and seems to represent the qualities the country needs. But eventually*

Table 6. Employment sector of respondents to NZ Institute of Chemistry salary surveys in 2000, 2006 and 2016.

2000		2006		2016	
Employment sector	***%***	***Employment sector***	***%***	***Employment sector***	***%***
Education	45%	University Secondary school	33% 6%	University School Polytechnic	42% 9% 1%
Public	20%	Crown Research Institute Central & Local Govt	19% 3%	Crown Research Institute Government agency	12% 6%
Private	35%	Private employee Owner / Director	29% 10%	Private company Self-employed	26% 2%
Other	0.4%	Other	9%	Other	2%

the very qualities which once seemed so admirable show their shadowy underside and come to viewed as discreditable. The same kind of switch into its opposite applies to the popularity of political parties. A party may successfully hold sway for a long period, but eventually it seems tired, no longer capable of governing effectively or in touch with the social forces which put it in power. This helps generate a sense of optimism that the party which is its main rival can provide a new government which is quite different: energetic, efficient, honest, more in tune with the country's needs. Its election to power is hailed as marking the start of a new, more hopeful era. For a while the new reforming government may enjoy a 'Dream' stage [see Table 3], when it seems it can do no wrong. But it gradually moves into a Frustration stage, when its errors and deficiencies seem to multiply. Finally, as the mood of the country shifts irreversibly against it, it enters a Nightmare stage where it can do nothing right; and by now, of course, the familiar momentum of optimism is building up around its opponents until the moment when they can sweep into power. Thus does the cycle of illusion and disillusion begin again.

Biennial reports of Research and Development in New Zealand compiled during the 2000s (*Research and Development in New Zealand* 2002, 2004, 2006, 2008, 2010, 2012) indicate a slow increase in the number of people employed in science (Figure 9), but remaining at about 1% of the workforce. Expenditure on research and development also increased modestly, slightly increasing as a proportion of gross domestic product (1.15% in 2002, rising to 1.27% by 2012).

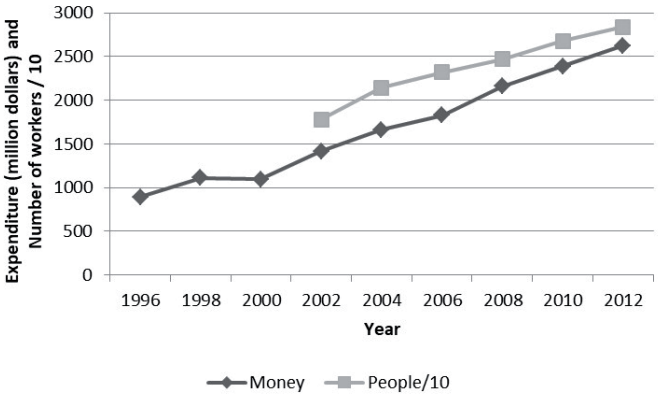

Figure 9. Research in the millennium decade – I. Modest increases in expenditure and personnel (being the sum of researchers, including student researchers from 2006), technicians and support staff.

The most significant change is in the proportion of expenditure on applied research, which has increased slightly over the period 2002–2012 at the expense of experimental and basic research (Figure 10). This trend is consistent with the applied focus of the missions of CRI research, and the likelihood that independent researchers or small companies do not have the facilities and resources to undertake basic and experimental research.

This protracted reform of the organisation of New Zealand's government science establishments transformed 'state science' into 'industrial science', in which the CRIs had to bid for funds, unlike the research associations whose funding relied on industry levies, was described by Galbreath (1998: 264–265) as:

The system of 'research associations' undertaking research for particular industries, and jointly funded by the industry and government (through DSIR), was based on the system developed in Britain from 1915. After the establishment of DSIR in New Zealand in 1926, a series of research associations were established in association with it. Most of them, although small, survived declining government grants and outlasted DSIR itself.

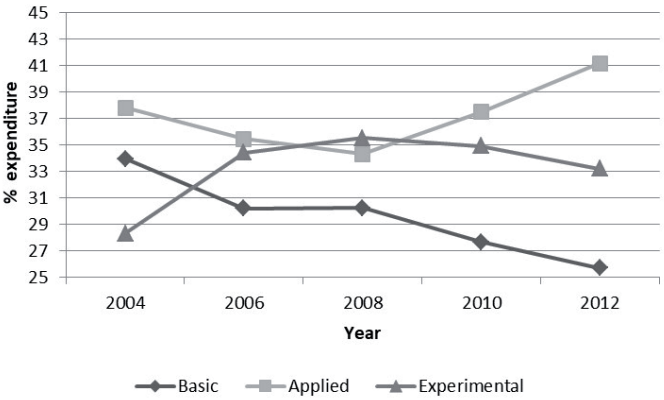

Figure 10. Research in the millennium decade – II. Changes in the proportion of expenditure on basic, applied and experimental research.

The current reality of this changed research environment is apparent in an analysis of the recipients of grants from the Marsden Fund (Royal Society of NZ 2017b) through which the Cawthron Institute received two grants each of $300,000: in 2014 ('Adaptive evolution in changing environments: can epigenetic variation compensate for low genetic diversity?'), and in 2016 ('Blooming buddies: explaining the co-existence of toxic and non-toxic strains in algal blooms'). Although Crown research institutes, smaller independent research organisations (e.g. Cawthron), and individual researchers do also seek and receive grants, the Marsden Fund clearly favours universities in terms of the number of projects supported (Table 7) and the amount of funds awarded (Table 8).

The situation is complicated slightly by the inclusion of independent researchers and those in other organisations as 'associate investigators' in projects for which the principal researchers ('principal investigators') are typically employees of universities or Crown research institutes. However, it is apparent that of the CRIs, GNS Science and NIWA dominate; and that CRIs dominate independent organisations / researchers: projects from the latter represent 14% of the combined number of CRI and independent projects (Table 7), and 12% of the funding (Table 8).

A counter-suggestion to this capture of most externally funded research by a small number of institutional 'players' is that the more recently developed National Science Challenges (MBIE 2016) would enhance the prospects of collaboration between CRIs themselves and between CRIs, universities and other researchers. Penman and Goldson (2015) supported this, indicating that this would provide for 'a balance of science excellence, effective boards, creating best teams free of institutional constraints, a focus on delivering outcomes and benefits, sharing of data and infrastructure, and engaging with wider society'. However, this optimistic suggestion of how the National Science Challenges might work has not eventuated. Table 9 shows a concentration of challenges in the universities, especially the University of Otago (with seven collaborations); and in two CRIs, viz. Geological and Nuclear Science, and Scion

Table 7. Research grants from Marsden Fund, 2012–2017: Annual number of projects supported.

Recipients	Number of projects supported						
	2012	*2013*	*2014*	*2015*	*2016*	*2017*	*All*
Universities / Wananga							
Auckland University of Technology	1	-	-	1	-	-	2
Lincoln University	-	-	-	-	1	-	1
Massey University	8	7	11	9	7	26	68
Te Wananga o Raukawa	-	-	-	-	-	1	1
University of Auckland	21	34	29	28	38	31	181
University of Canterbury	5	11	6	5	7	11	45
University of Otago	22	22	22	18	23	32	139
University of Waikato	6	3	4	4	5	4	26
Victoria University of Wellington	12	21	24	13	26	17	113
All participating universities / wananga	*75*	*98*	*96*	*78*	*107*	*122*	*576*
Crown Research Institutes							
AgResearch	-	1	-	-	-	-	1
GNS Science	5	4	1	4	-	2	16
Industrial Research Limited / Callaghan	2	1	-	-	2	-	5
Institute for Environmental Science & Research	-	-	-	-	1	-	1
Landcare Research	1	1	-	1	1	3	7
NIWA	2	1	-	1	3	4	11
Plant and Food Research	-	2	-	3	-	1	6
Scion [Forest research]	-	-	1	-	-	-	1
All participating Crown Research Institutes	*10*	*10*	*2*	*9*	*7*	*10*	*48*
Independent institutions / researchers*							
Bodeker Science	-	-	1	-	-	-	1
Canterbury Museum					1	-	1
Cawthron Institute	-	-	1	-	1	-	2
Dragonfly Science	-	-	1	-	-	-	1
Malaghan Institute for Medical Research*	-	-	-	1	-	-	1
MOTU [Economics research]	1	-	-	1	-	-	2
All participating independent science institutions / researchers	*1*	*0*	*3*	*2*	*2*	*0*	*8*

*The Malaghan Institute for Medical Research, which was awarded a research grant in 2015, subcontracts to one of the organisations in this table, and may be a partner in future applications to the Marsden Fund. Medical research receives significant funding from the Health Research Council. The Malaghan Institute, the Medical Research Institute of New Zealand, and three Maori health research independent research organisations have all received significant funding from this source since 2014.

(each with four collaborations). Collaboration is skewed towards a small number of institutional 'players'; or as Aref *et al* (2018) express it, *'Constructing a collaboration network of institutions, we observe a power-law distribution indicating that a small number of New Zealand institutions account for a large proportion of national collaborations.'*

Although the staff numbers of Table 9 can only be considered indicative, Figure 11A suggests that involvement in these collaborations appears to favour larger institutions. However, a maximum in the polynomial line of best fit (Figure 11B) suggests that there may be an optimum size of an institution that participates in such challenges.

Conclusion

The history of Nelson's Cawthron Institute started with the realisation of a colonist's vision for science in his home-region of New Zealand, and the establishment of a private research establishment through the concordance of the initial Cawthron vision with chemistry professor T.H. Easterfield's pragmatism. Over the ensuing years the Institute formed and lost relationships with bigger players but survived. In light of the current dominance of science research by large organisations (i.e. the Crown research institutes that supplanted DSIR, the government entity Callaghan Innovation; and the universities), Cawthron can still 'hold its own' with the larger players. Cawthron may even inspire smaller research organisations and independent researchers to continue to participate in scientific research in New Zealand.

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Table 8. Research grants from Marsden Fund, 2012–2017: Annual funds distributed.

Recipients	Annual funds distributed ($000)						
	2012	*2013*	*2014*	*2015*	*2016*	*2017*	*All*
Universities / Wananga							
Auckland University of Technology	345	0	0	670	0	0	1015
Lincoln University	0	0	0	0	300	0	300
Massey University	5585	2987	6176	5230	3105	15627	38710
Te Wananga o Raukawa	0	0	0	0	0	845	845
University of Auckland	13435	16268	15985	16619	20630	19752	102689
University of Canterbury	1935	5511	3655	3812	4900	6375	26188
University of Otago	14190	13024	13908	11153	13735	20615	86625
University of Waikato	3605	2265	2420	1310	3035	2712	15347
Victoria University of Wellington	6750	11230	10822	8045	14350	9256	60453
All participating universities / wananga	*45845*	*51285*	*52966*	*46839*	*60055*	*75182*	*332172*
Crown research institutes							
AgResearch	0	826	0	0	0	0	826
GNS Science	4120	2099	695	2575	600	600	10689
Industrial Research Limited / Callaghan	690	695	0	0	0	0	1385
Institute for Environmental Science & Research	0	0	0	0	830	0	830
Landcare Research	920	300	0	300	830	2150	4500
NIWA	1300	739	0	300	2020	2358	6717
Plant and Food Research	0	1504	0	1440	0	895	3839
Scion	0	0	300	0	0	0	300
All participating Crown Research Institutes	*7030*	*6163*	*995*	*4615*	*4280*	*6003*	*29086*
Independent institutions / researchers							
Bodeker Science	0	0	785	0	0	0	785
Canterbury Museum	0	0	0	0	300	0	300
Cawthron Institute	0	0	300	0	300	0	600
Dragonfly Science	0	0	300	0	0	0	300
Malaghan Institute for Medical Research	0	0	0	840	0	0	840
MOTU	890	0	0	300	0	0	1190
All participating independent institutions / researchers	*890*	*0*	*1385*	*1140*	*600*	*0*	*4015*

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Table 9. Institutional participation in New Zealand's National Science Challenges.

Collaboration partners		Staff†	National Science Challenges*							Σ‡
			1	*2*	*3*	*4*	*5*	*6*	*7*	
Universities ❶										
U1	Auckland University of Technology	1183		●			●			2
U2	Lincoln University	200		●	●	●	●			4
U3	Massey University	1339	●	●	●	●	●			5
U4	University of Auckland	2232		●	●	●	●	●		5
U5	University of Canterbury	749		●		●	●	●		4
U6	University of Otago	1552	●	●	●	●	●	●	●	7
U7	University of Waikato	599		●	●		●	●		4
U8	Victoria University of Wellington	1062		●		●	●	●	●	5
Crown research institutes ❷										
C1	AgResearch	700	●	●			●			3
C2	Institute of Environmental Science and Research	400		●	●		●			3
C3	Institute of Geological and Nuclear Sciences	332		●	●			●	●	4
C4	Landcare Research	283			●				●	2
C5	National Institute of Water and Atmospheric Science	454		●	●	●				3
C6	Plant and Food Research	675	●	●	●					3
C7	Scion [Timber-related research]	321		●	●	●	●			4
Government agency ❸										
G1	Antarctica New Zealand	36							●	1
Independent institutions ❹										
I1	Building Research Association of NZ	100				●				1
I2	Cawthron Institute	220						●		1
I3	Lincoln Agritech	59			●		●			2
I4	Opus International Consultants	23				●				1
No. of collaboration partners in each challenge			4	14	12	10	12	7	5	

*National Science Challenges: ***1***, High-value nutrition; ***2***, New Zealand's biological heritage; ***3***, Our land and water; ***4***, Resilience to nature's challenges; ***5***, Science for technological innovation; ***6***, Sustainable seas; ***7***, The Deep South.

† Estimated from information available in annual reports or websites; the distribution of staff across academic, professional, administrative are not consistent between organisations. If only the total staff number is listed, it is assumed for the purposes of Figure 11 that half are involved in research. For universities the number of all academic staff reported in annual reports is halved for the purposes of Figure 11, on the basis of there being a 50:50 split between teaching and research commitments of academic staff. Where specified, technical are included but administrative staff are excluded.

‡ Σ is total number of challenges in which collaboration partner participates.

❶ For universities: U1, https://www.aut.ac.nz/__data/assets/pdf_file/0007/119815/diversity-infographic-page-v6.pdf ; U2, http://www.lincoln.ac.nz/Documents/Marketing/Publications/Annual-Reports/AnnualReport2017.pdf ("Academic 200 (31%)" of 643 FTE); U3, https://www.massey.ac.nz/massey/fms/About%20Massey/University-Management/documents/annual-report/massey-university-annual-report-2017.pdf?ED32BC3335191A5A35230F1A1D93401B (2017); U4, https://cdn.auckland.ac.nz/assets/auckland/about-us/the-university/official-publications/annual-report/2017-annual-report-university-of-auckland.pdf (2017); U5, https://www.canterbury.ac.nz/media/documents/annual-reports/Annual-Report-2017-Full.pdf (2017); U6, https://www.otago.ac.nz/about/official-documents/otago684398.pdf (2017); ….. U7, https://www.waikato.ac.nz/annualreport/ (2017); U8, https://www.victoria.ac.nz/__data/assets/pdf_file/0008/756008/2017-annual-report.pdf ("teaching and research staff" in 2017).

❷ For Crown Research Institutes: C1: https://www.agresearch.co.nz/assets/Uploads/AgResearch-Annual-Report-2018-for-web.pdf includes "scientists, technicians and farm support staff"; C2: https://www.esr.cri.nz/home/about-esr/ ('expert minds'); C3, https://www.gns.cri.nz/Home/About-Us/Corporate-Documents/Annual-Reports/2018-Annual-Report ("Over 85% of our staff [> 390] are directly involved in science"); C4, https://www.landcareresearch.co.nz/about/people/science-teams ; C5, https://www.niwa.co.nz/about/our-people (590 staff; annual report indicates 76.9% are scientists or technicians); www.niwa.co.nz/static/web/NIWA13387_2018-Annual-Report_13LR_Web.pdf); C6, https://www.plantandfood.co.nz/page/our-people/ ("We have over 900 people, 75% of who are working in our science operations teams"); C7, https://www.scionresearch.com/__data/assets/pdf_file/0007/64924/Scion_2018_AR_PartA.pdf ("includes fixed-term, student and postdoctoral staff").

❸For the Government agency: G1, http://www.antarcticanz.govt.nz/about-us/our-people/

❹For independent institutions: I1, https://www.branz.co.nz/cms_display.php?sn=401&st=1; I2, https://www.cawthron.org.nz/analytical-services/news/2018; I3, https://www.lincolnagritech.co.nz/about/our-team/; I4, https://www.wsp-opus.co.nz/assets/Uploads/PDFS/Opus-Research/2016-Opus-Research-Booklet-march.pdf (probably excludes technicians)

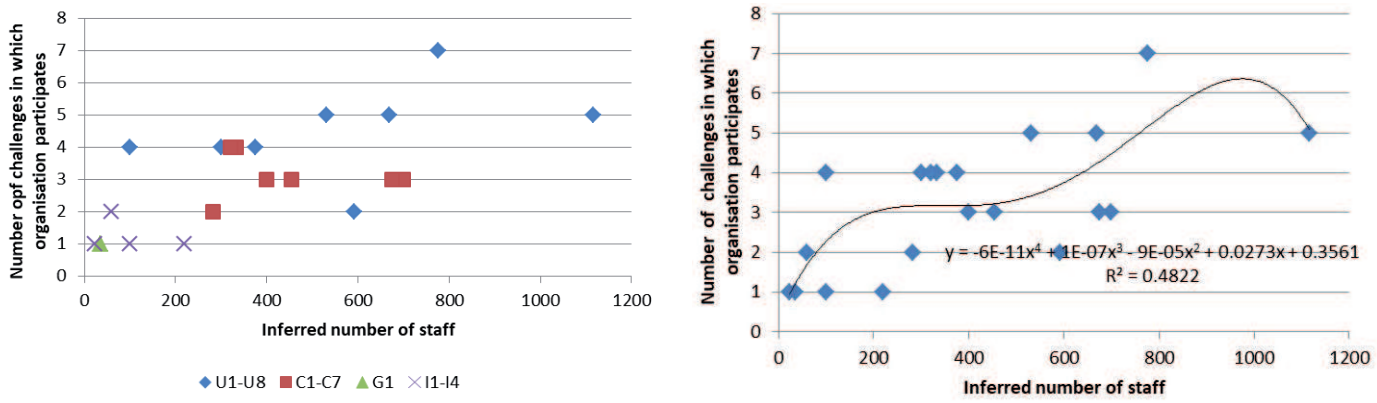

Figure 11. Variation of number of challenges with institutional size.

A (left): Universities, U1-U8; Crown research institutes, C1-C7; Antarctica New Zealand, G1; Independent institutions, I1-I4.

B (right): Line of best fit for all data is a 4th-order polynomial, with a correlation coefficient of 0.48.

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