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The evolution of New Zealand's Antarctic research programme since 1957

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ABSTRACT. New Zealand's Antarctic research began during the 1957/1958 International Geophysical Year. This analysis explains how and why it has evolved. There have been two phases: 1957 until 1991, when the Department of Scientific and Industrial Research and the universities were the key research organisations, and after 1991, when the publicly funded research sector became more diverse. International collaborations have been important throughout. Funding decision processes have progressed from a bottom-up curiosity-driven approach to a more complex system of regular contests. Since 1991, the focus has been on coherent strategies and the outcomes sought. Funding criteria are well-defined and contests are widely accepted as fair and transparent. Reviews and evaluations have been positive. Collaborative organisational interactions dominated decision-making during the early period. Bureaucratic politics is most evident in post-1991 organisational changes. The quality of the research strategies has improved in terms of defining outcomes sought and appropriate measures of progress towards them. However, New Zealand's Antarctic research funding is currently dispersed. It needs better coordination. Collaborative research should be emphasised in areas where New Zealand has established a strong reputation taking account of both national and global priorities if New Zealand's international research standing is to be maintained and enhanced.

Introduction

New Zealand's scientific Antarctic research and its overall science system have both evolved considerably since Scott Base was completed in 1957/1958. Analysing how and why is interesting because New Zealand has been one of the most prolific generators of Antarctic research papers, funding decision processes have progressed from a bottom-up curiosity-driven approach to a more complex system of regular contests, and some of the work now has global policy relevance.

This paper largely references the various public domain planning documents, strategies and evaluations that have been released over time in order to assess how positive or negative the changes that have been made have been and to suggest some areas where improvements could still be made. It does not attempt to assess the science in detail. University and government researchers have published thousands of Antarctic papers since 1957. Any judgement of their merits would be a massive task and would inevitably provoke disagreement from those who considered their research area slighted.

The analysis is based partly on interviews with a number of the New Zealand-based Antarctic researchers from universities and the key public service research organisations, science system policy analysts and other participants actively involved, most of whom the author first met during his 2000–2013 policy work in the science funding system. The discussions focused primarily on issues relating to why the system and science changed, and on how these changes affected collaboration and competition at the individual, organisational and international levels. The nature of these discussions varied widely, depending on the role that each person played in Antarctic research or policy work and when they were actively involved. No-one who was asked for a contribution declined to be interviewed.

Decision-making models

Three broad approaches were used to analyse how research funding and system design decisions may be made and evaluated. They are not mutually exclusive. Each has a distinctly different focus. All have useful explanatory power.

Economic rationality

Deciding what science to fund is essentially a resource allocation decision, given that there are nearly always more projects proposed than research and logistics funding available. How such decisions are taken can benefit from applying analytical techniques that balance the potential gains against the scientific and other risks, uncertainties and costs involved. This approach, which focuses on outputs more than inputs, has been used increasingly widely by the public and private sectors since the 1970s.

Commonly used analytical methodologies include a range of discounting techniques, in which the costs and future benefits are forecast and discounted back to the present. The research goals sought are typically economic, environmental, social, pure knowledge or a mix. Doing this is often feasible for economic goal research (which most Antarctic research is not) but is usually much harder for other work. A key factor distinguishing scientific funding from other resource allocation decisions is that research results and their value are usually uncertain in advance. Quantitative analytical techniques can simply be too hard to apply effectively (Morten, 2006). In any case, the discounting principle seems questionable for decisions with long-term sustainability consequences, which are the norm in environmental economics. Nevertheless, such analyses are sometimes feasible when the benefits are savings made by using evidence to avert or mitigate environmental damage through accelerating appropriate local or global policy changes. For example, considerable work has been done on the risks and costs of climate change and the benefits of limiting it (for example, Stern, 2006).

New Zealand and other funding agencies and coordinating bodies have instead developed funding criteria in order to break a funding decision down into its components. The key criteria are all scored. Where quantitative approaches can be used in a cost-effective manner, they can make the process less subjective, for example bibliometric analysis for researchers' productivity and citation analysis for a paper's impact. If the criteria are well-defined and are independent of one another, this is usually an effective way of ranking proposals, especially if some of the review panel members are experts in the science disciplines under consideration and have no conflicts of interest. The criteria and the key factors affecting the scores are specified in advance. If necessary, balancing factors can also be applied to ensure a sound dispersal of work across disciplines or for other reasons (Morten, 2006).

Another rational approach for public sector research funding is periodically to develop an overall research strategy, where stakeholders collectively agree the key questions that need to be investigated and the central outcomes that are being sought, together, for ongoing programmes of work, with objective measures of progress being made towards the desired outcomes. The processes involved in designing a strategy may well involve elements of the second and third decision-making approaches described below. Specific proposals are assessed by how well they match the chosen strategy, with research and logistical costs part of the mix. Retrospective evaluations can be made to determine how well the work done has achieved the objectives. By way of contrast, the 'muddling on' approach is to keep researching an issue or following a strategy until diminishing returns have unequivocally set in. This is more likely when funding decisions are driven by input considerations, rather than by measuring outputs and the contribution of the work undertaken to well-defined outcomes. Periodic contests, reviews and evaluations tend to mitigate against such 'muddling on' (Lindblom, 1979).

Organisational interactions

Analytical rationality is often insufficient when considering how people and organisations with differing objectives and personal goals interact in the real world, where decisions typically involve a group of loosely allied stakeholder organisations rather than a single, rational, completely informed, centrally-controlled and value-maximising decision-maker.

In the organisational interaction model, stakeholders have separate goals and differing abilities to influence funding decisions. Public sector coordination is achieved through ministers, who may issue directives, and more directly among organisations by persuasion, negotiation and the use of power. Each organisation uses its own standard operating procedures, which evolve slowly as the working environment changes (Allison, 1971; Simon, 1957). Organisations tend to repeat what has worked in the past. Crises may not be handled well. Often, not much long-range planning is done. They will compete rather than cooperate if the resources available become severely constrained (March, 1965).

For New Zealand's Antarctic research, one relevant factor is whether some of the organisations involved have cared enough to need to influence the decision-making process. When the sums and issues involved are not seen as critical, some simply decide that they have 'bigger fish to fry'.

Bureaucratic politics

This model goes one step further. Organisations are not monolithic. They comprise individuals who may be involved in centralised, competitive games. This is not in itself a bad thing – it is simply how the world functions. Players may have one key focus (for example, obtaining funding for their particular research project) or they may be seeking personal or political advantages in a variety of ways, such as through organisational or systemic change. The processes of interaction, of pushing and pulling and of bargaining and conflict, can lead to an outcome that results more from the forces applied than from any individual's original intentions (Allison, 1971; Nossal, 1979). The ability and skill with which players use their influence and take advantage of their opportunities is important.

This kind of behaviour tends not to be documented in official papers. Diaries mislead and memories fade and colour. An early theorist who used this approach has written:

> If I were forced to choose between the documents on one hand, and late, limited, partial interviews on the other, I would be forced to discard the documents (Allison, 1971).

This is one of the reasons, but not the only one, why the author has used interviews extensively in writing this paper. A second key factor was simply to help resolve what key events occurred and why, and who else best to discuss them with.

The roles and interests of the key stakeholders

Even in a relatively small science system such as New Zealand's there are many stakeholders. They have changed over time. A key split occurred in 1991. What follows is an overview.

The government

New Zealand's government system is similar to the UK's, but without a House of Lords. The Minister of Science was responsible until 1991 for the Department of Scientific

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and Industrial Research (DSIR) and between 1991–2010 for the Ministry of Research, Science and Technology (MoRST) and the Foundation for Research, Science and Technology (FRST), a key funding agency. Since 2012, ministerial control has mainly been exercised through the Ministry of Business, Innovation and Employment (MBIE). The Minister of Finance and the Cabinet have been directly involved in new expenditure decisions throughout, for example: budget bids for extra science for the 2007/2008 International Polar Year (IPY); large capital items, such as for renovating Scott Base and purchasing new research vessels and aircraft; and in making cutbacks when funding was tight. Research funding decisions on individual projects or linked programmes have always been delegated.

Departments and ministries

The DSIR was a key government department for Antarctica until it was disestablished in 1991. The Ministry of Foreign Affairs and Trade (MFAT) has funded land-based logistics throughout, through the Ross Dependency Research Committee (RDRC) and later Antarctica New Zealand (AntNZ). After 1991, MFAT absorbed the policymaking aspects of the DSIR's Antarctic Division. Its main interests have been geopolitical. From 1991–2011, MoRST had primary responsibility for science policy but did not itself fund any Antarctic science. Science policy responsibility is now held by MBIE. Other departments and ministries, such as environment, defence, works and development, conservation and fisheries have each had specialist interests.

The research institutions

While it existed, the DSIR undertook much of the research, especially during the early years. Three of the current seven Crown Research Institutes (CRIs) created from the DSIR have been extensively involved in the Antarctic: the National Institute of Water and Atmospheric Research (NIWA), GNS Science (GNS) and Landcare Research. They are structured as state-owned enterprises (that is, companies). All eight New Zealand universities have or have had Antarctic researchers. They have undertaken roughly half the research.

International

The Antarctic Treaty System (ATS) agreements and agencies have considerable control over what may and may not be done in and around the continent. New Zealand's Antarctic logistics and research operations have been closely linked with those of the USA and other nations since Scott Base's inception. This has occurred formally through research collaborations, and informally through sharing logistics operations and by hosting researchers from other nations at Scott Base and elsewhere.

Research and logistics funding sources

Before 1991, the main domestic science funding sources were Vote: Science, for the DSIR's research, and Vote: Education, for the universities. New Zealand co-funded a considerable amount of collaborative research with international partners. Funding was not contestable in the modern sense. Research proposals needed approval from the RDRC for logistical costs, which research organisations on the whole did not pay.

Since 1991, the situation has become much more complex:

- AntNZ has handled the on-land logistics and some non-science programmes since 1996.
- FRST ran separate Antarctic research contests until about 2000 and for environmental science funding until 2010. It was the main funder of the CRIs. MBIE now runs much more generic research contests.
- The New Zealand Royal Society (NZRS) manages the Marsden Fund, which was established in 1994 for untargeted 'blue skies' research in any field, and Rutherford Discovery Fellowships (five years of research funding for ten individuals a year, across all fields of science nationwide, established in 2013).
- The CRIs and universities all have a certain amount of non-contestable core funding. NIWA pays the logistical costs for the research vessel *Tangaroa* through its core funding and by contracting to undertake oceanographic research, only some of which is done in the Southern Ocean region.
- The Tertiary Education Commission (TEC) controls some discretionary university research funding.
- The New Zealand Antarctic Research Institute (NZARI) has run small funding rounds since 2012.
- MBIE and reallocated CRI core funding support to the 'Deep South', one of 11 collaborative national science challenges which began in 2013.
- The USA funds its research and logistics through the United States Antarctic Programme (USAP). Its main science funding agency, the National Science Foundation (NSF), is a key funder of international collaborative programmes. New Zealand scientists cannot apply directly to it.
- Virtually none of New Zealand's Antarctic research is funded directly by the private sector.

Coordinating bodies

The RDRC was the main logistics and science coordinating body until 1996. Since then, AntNZ has had a general logistics, but not directly a science, coordination role. The NZRS has managed New Zealand's formal links with international bodies since 1957.

The DSIR period (1957–1991)

The 1957/1958 IGY and the 1958/1959 International Geophysical Cooperation Year

New Zealand took over the UK's claim to the Ross Dependency in 1923 but did little to substantiate this until after World War II (Quartermain, 1971). In 1953, the UK started planning a Trans-Antarctic Expedition (TAE) from the Weddell Sea to the Ross Sea. It and the

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USA urged New Zealand to set up a station at the Ross Sea for the TAE and for the International Geophysical Year (IGY) science programme, which was planned for 1957/1958. The prospect of Christchurch becoming an Antarctic gateway city for the USA's Operation Deep Freeze, Sir Edmund Hillary's involvement in the TAE and the urging of the NZRS and of the New Zealand Antarctic Society helped persuade the Cabinet to agree in 1955 to provide significant funding for the TAE and for Scott Base, which ended up being sited close to the USA's McMurdo Station (Quartermain, 1971). New Zealand's component of the TAE cost £400,000, including the construction of Scott Base. The government paid £243,000. The rest was raised by public subscription. The IGY cost a further £44,000, not counting DSIR and meteorological service costs (Quartermain, 1971).

The programme for the IGY was drawn up by the International Council of Scientific Unions, which in 1958 created the Scientific Committee on Antarctic Research (SCAR). The IGY involved observations being made at over 1,000 stations all over the earth. 1958 was a sunspot maximum year, which helped certain observations. The IGY coordinated world-wide observations across a broad range of disciplines. Individual nations with Antarctic stations also started to map their claims.

According to the RDRC's 1959 report to SCAR, a particular New Zealand focus was investigating the propagation of radio waves through the upper atmosphere, especially in the aurora zone and of 'whistlers'. Some oceanographic work was undertaken. Not much biology was undertaken, as biology was not supposed to be a feature of the IGY, although some initial studies were made.

Cabinet agreed in March 1958 to a one year extension to the IGY (DSIR, 1958). It continued the Scott Base programmes, using cameras and other automatic recording devices rather than human observers. It also supported geological and topographical mapping in Victoria Land, with US support; oceanographic work on the research vessel *Endeavour*; further geological mapping and some geophysics work in the Dry Valleys; and a wider range of biological research. The RDRC and the DSIR's Antarctic Division were both created in 1959 (DSIR, 1959).

The Antarctic Treaty and SCAR

The successful negotiation of the Antarctic Treaty during 1958 and 1959 can at least in part be attributed to the success of the IGY. It was negotiated and signed by the 12 states that had erected year-round Antarctic stations during or before the IGY. Its key articles are:

- Articles 1 and 5 set Antarctica aside for peaceful and scientific purposes and demilitarised it. No nuclear testing or dumping is allowed.
- Article 2 ensures the freedom of scientific investigations and cooperation.
- Article 3 promotes the free exchange of information and personnel.
- Article 4 is an 'agreement to disagree' on sovereignty claims. It freezes existing territorial claims.
- Article 6 defines the treaty's domain as all land, ice shelves and surrounding waters below 60°S.
- Article 9 states that Antarctic Treaty Consultative Meetings (ATCMs) are to take place at suitable intervals and places among member nations. These were at first held biennially. They now take place annually.

This was all very satisfactory from New Zealand's geopolitical perspective, as while the treaty remains in force, it removes the possibility of any hostile state occupying a huge area of land that is relatively close by. It has meant that by working within an effective rules-based system, New Zealand can influence other more powerful nations. Science and collaboration in practice have since become commonly accepted as the currency of diplomacy in Antarctica (Brady, 2012, p. 15).

The ATS has evolved since 1959. It now includes:

- Measures for the Conservation of Antarctic Fauna and Flora (1964); and, later, of seals (1972).
- The Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR) (1982).
- The Protocol on Environmental Protection (PEP), also known as the Madrid Protocol (1991).

The PEP requires an environmental impact assessment to be made before undertaking new activities within the ATS area. It has increased the focus on carefully managing environmental waste and on removing unused facilities. It began in 1981 in a series of meetings chaired by New Zealander Chris Beeby aimed at drafting a Convention on the Regulation of Antarctic Mineral Resource Activities (CRAMRA). The prospect of mining in Antarctica had by then attracted many new nations to join the ATS. In a surprise move in 1989, Australia and France proposed the more restrictive PEP, which was adopted.

MFAT plays an ongoing key role in developing New Zealand's policy positions at ATS meetings and in producing relevant New Zealand legislation, such as the Antarctica Act 1960, the Antarctica (Environmental Protection) Act 1994 and the New Zealand Antarctic Institute Act 1996.

SCAR provides scientific advice to the ATS through ATCMs or in between these, as asked. SCAR has evolved as membership of the ATS has grown and as the breadth and relevance of Antarctic research has advanced (Walton, Clarkson, & Summerhayes, 2011).

New Zealand's Antarctic achievements between 1957 and 1991

Scott Base has been the key New Zealand station throughout. It was rebuilt and expanded after 1976. Eleven people on average overwinter each year. Cape Hallett and Vanda Stations were built later but were eventually removed. Other summer huts and camps have also been created from time to time.

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Considerable scientific progress was achieved from 1957 to 1991. The RDRC wrote annual reports on New Zealand's Antarctic research and other Antarctic achievements. These were attached to the annual DSIR reports to parliament (RDRC, 1959–1991). These reports have been the primary sources for the content of this part of the paper, together with a 1957–1982 DSIR Antarctic achievements overview (DSIR, 1983).

- Oceanographic work was limited, as New Zealand lacked a suitable research vessel for much of this period. HMNS *Endeavour* was active from 1956 until 1961, and a second *Endeavour*, a converted tanker, from 1963 until 1971. Several RDRC annual reports after that commented on the need for a permanent ship but it was not until 1991 that the *Tangaroa* came into service.
- Scott Base work on the interaction of the solar wind, the upper atmosphere's magnetosphere and on radio transmission shed light on mechanisms in the ionosphere and on terrestrial weather. Measurements were made of atmospheric pollutants and of radioactivity traces from nuclear testing. New Zealand started making regular ozone measurements at the joint New Zealand/USA Arrival Heights laboratory soon after the spring ozone hole was discovered. It still does so.
- Reconnaissance phase topographical and geological mapping of the Ross Dependency was largely completed by the early 1970s, with New Zealand geological parties contributing to *Folio 12 – Geology* of the American Geographical Society's *1970 Antarctic map folio*. Aerial photography was widely used, with American air support. Areas noted in the exploration phase as being especially interesting, such as the Dry Valleys, began to receive more detailed investigation.
- From 1975, geophysical surveys across the Trans-Antarctic Mountains were used to gather data to reveal the causes and timing of their uplift history and of the role of glaciation in shaping them.
- Fossil fish remains, coal and fossilised plants were known from the Trans-Antarctic Mountains from the pre-World War 1 Heroic Era, but extensive mapping by New Zealand parties revealed their full extent, with vertebrate fossil discoveries by New Zealand and US parties demonstrating former land connections with other fragments of the Gondwana supercontinent.
- New Zealand geophysicists were involved in some onshore mapping and offshore marine seismic surveys of the Ross Sea in the 1970s and 1980s to expand geological knowledge, as well as providing an indication of the chances of finding petroleum. No significant discoveries were made. The 1976 RDRC annual report stated that there was little evidence of mineral or hydrocarbon deposits on land which would be attractive to commercial exploitation.
- Birds, seals and fish were extensively counted and studied, together with more primitive life forms in the Dry Valleys lakes. Their adaptations to survive freezing and harsh winters began to be investigated. Work on the very slow formation of soils was undertaken.
- Biologists made extensive studies of the Ross Sea and Dry Valleys ecosystems and chemists found the reason for the unexpected year-round warmth of the water at the bottom of Lake Vanda. Glaciologists began annual surveys of glaciers, the Onyx River and Lake Vanda in Wright Valley in 1968/1969, beginning a time series that continues today.
- New Zealand biologists also contributed to the SCAR BIOMASS project, a ten year 1980s survey of marine Antarctic ecosystems and stocks that provided the scientific foundations for CCAMLR.
- Following the first ocean floor drilling on the Antarctic margin by the Deep Sea Drilling Project in 1972, the Dry Valleys Drilling Project (New Zealand, USA and Japan) began geological drilling in the Dry Valleys in 1973 and 1974, and in McMurdo Sound in 1975, for the extent and timing of past ice sheets during glacial and interglacial periods. Offshore drilling from the sea ice continued in 1979 and 1984, but proved difficult. Success in recovering early ice sheet records (as far back as 34 million years ago) was not achieved until 1986.

Overall, there was a slow trend in research away from routine environmental and biological work and small independent operations towards longer-term interdisciplinary and international efforts, which were increasingly seen as offering better value for money. Until 1978, the RDRC annual reports listed separately all of the international research programmes in which New Zealand took part. The 1979 RDRC annual report stated that so much work was now being done with other nations that the international projects section of the report was being discontinued.

By the end of 1982, New Zealand researchers had published 1,484 papers in recognised journals. New Zealand was then the third most prolific producer of Antarctic scientific papers (DSIR, 1983).

Strategies, reviews and evaluations pre-1991

No detailed strategic or evaluation work appears to have survived from before the 1980s, other than some skimpy work plans and what is contained in the RDRC and DSIR annual reports to parliament:

> The present programme consists basically of three parts: (a) semi-permanent observatory-type physical measurements…(b) land-based biological and ecological observations…and (c) geological / geochemical / geophysical and glaciological measurements in the Trans-Antarctic Mountains (including the Dry Valleys) and on the McMurdo Sound Volcanics (RDRC annual report 1978).

'Future directions in New Zealand Antarctic research', RDRC 1985

Global environmental and other research was evolving quickly by the 1980s. Tectonic plate theory was accepted

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in the 1970s. The spring ozone hole over Antarctica was discovered in 1984. Global climate change caused by greenhouse gases became a major international concern soon afterwards. Antarctica became a key place to study related events, such as the drivers of sea level change. The contributions Antarctic research could make in several important policy areas increasingly mattered and began to receive global policy attention. The need for proper programme planning was growing.

The RDRC produced its 'Future directions in New Zealand Antarctic research' strategy in 1985. It stated that this was the first detailed New Zealand Antarctic research strategy to be circulated widely. It commented that the work programme was still derived in general from annual proposals from universities, government agencies and a few from overseas, proposing collaborations:

> In order to give continuity to apparent short-term planning, the RDRC has three Working Groups … whose duties are to comment on the scientific merit of the annual proposals and to prepare five year projections of desirable and possible research in their areas… Policymakers responsible for the use of public funds are increasingly loath to leave science to the scientists and must be satisfied that appropriate planning mechanisms are in place (RDRC, 1985).

In biology, proposed work focused on physiological adaptations, on how Antarctic ecosystems function normally, and on how they might respond to commercial exploitation. The importance of identifying and protecting important sites and biological communities was emphasised.

Most of the earth sciences work proposed was basic research on fundamental problems of Antarctica's geological history, involving opportunistic marine seismic surveys and more purposeful sea floor drilling from the sea ice, plus local and deep field work. Studies were proposed on three major sedimentary basins thought to have hydrocarbon potential, though they were done mainly for the geological history they could reveal. The physical sciences proposals look very like a continuation of the IGY programmes, with sea ice and glacier ice studies expanded.

'Antarctic science – science activity review no. 1', DSIR 1988

The DSIR began running internal contests in the late 1980s. In 1988, it published the first of a proposed series of backward- and forward-looking reviews, 'Antarctic science – science activity review no. 1' (DSIR, 1988). This involved widespread stakeholder consultation. It recommended:

- Developing more cooperative interdisciplinary programmes, such as the Ross Ice Shelf Ecosystem study, rather than allowing individuals to continue disparate lines of research.
- Moving the emphasis to understanding processes as well as collecting isolated data.
- Changing to identifiable science activity areas (that is, earth, physical and life sciences) would help the Director-General insist on more collaboration, coordination and purpose by DSIR scientists.
- Expanding logistical capabilities to extend science capability into new areas.
- Increasing international collaborations, as these extended the amount and type of information New Zealand could access and developed science expertise.

The report noted that this was New Zealand's first general Antarctic science evaluation since the 1957/1958 IGY. It concluded that DSIR scientific research since then was recognised internationally for its high quality and large output, which gave credibility and weight to New Zealand at ATS meetings. It added that the praise was remarkable, given the programme's lack of obvious cohesion and occasional logistical constraints. Other benefits from the research included monitoring atmospheric and nuclear pollution and the ozone layer, biota and seismic activity, and the production of new knowledge. However, the report included no bibliometric or other quantitative evaluation data.

It stated that compelling reasons to continue with an active research programme were to study:

- Antarctica's effects on New Zealand's and the globe's climate and environment.
- The close geological links between the Ross Dependency area and New Zealand.
- The undisturbed snow, ice cap and sedimentary histories of global climate changes.
- How life had adapted to the extreme conditions.
- A range of phenomena that only occurred at the poles.

The review charted the numbers of various types of personnel in Scott Base and other New Zealand Antarctic sites from 1958 to 1988 (DSIR, 1988, p. 43). This showed that there were more university than government scientists in Antarctica in most years after 1980, plus a steadily increasing number of guest foreign researchers. It also stated (DSIR, 1988, p. 4) that funding for the DSIR's Antarctic Division rose from $157,212 in 1959/1960 to $3.333 million in 1988/1989. This amounted to a doubling in inflation-adjusted terms.

New Zealand's Antarctic programme administrative processes from 1957–1991

The RDRC was an unusual advisory body. The DSIR ran it through its Antarctic Division and provided the bulk of its members, but most New Zealand-based organisations undertaking research or providing services in Antarctica were represented on it, public sector or not. Many of the people actively involved over much of this period are still alive. Almost universally, those with whom the author has spoken have said that the RDRC worked well, without significant acrimony or gamesmanship, other than members seeking support for their own research proposals. The Antarctic research community was relatively small and

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knew each other in ways perhaps not possible in large nations. They were prepared to make accommodations.

> Antarctic research programmes presented by the RDRC to the Minister for approval in general comprise projects initiated by university and government departments, usually by the individual scientists therein. The Committee in shaping the programmes takes advice on the likely logistical constraints…The level of the programme is determined by the Committee's ideas on what is likely to be politically acceptable… Thus the scientist, logistical and politically acceptable levels determine the programme, with a final shaping by the RDRC (RDRC, 1979, annual report).

Active participants asked by the author to describe the RDRC's and DSIR's decision processes said:

> The science done in the early years was a bit random and opportunistic. Until 1970 or so, it was largely bottom-up-driven basic exploration for knowledge. In the DSIR, Antarctica was small. Budget arguments were on a larger scale. You just had to persuade your Director … I had trouble persuading DSIR scientists to put together a coherent programme when I was trying to coordinate things. It remained mainly bottom-up at both the DSIR and universities (Dr F. Davey, DSIR policy team, RDRC member, GNS, 2015 interview).
>
> Money was seldom a key constraint. The universities paid their researchers' salaries. Field and Scott Base costs were largely covered by the RDRC and the USA. There was seldom a resourcing problem. The RDRC provided some science merit overview. The quality of the universities' work was variable. Proposals from serious, keen scientists usually made sense. People who just wanted to do 'science' could stay in New Zealand. There were no power games. However, the RDRC did not plan far enough ahead. It just considered matters season by season (Dr E. Robertson, Chair of the RDRC and Director-General of the DSIR 1971–1981, 2016 interview).
>
> New Zealand's dispute with the US in 1984 over nuclear-powered warship visits did not affect US-New Zealand relationships in Antarctica. It has always remained a domain of international cooperation, with a focus on pure science and a tacit hunt for resources. Much of our work was niche research (Dr P. Winsley, DSIR policy team and at Chief Policy Adviser at FRST 1995–2000, TEC, 2015 interview).
>
> Antarctic research was the one DSIR science area where curiosity was encouraged. The RDRC did not provide a strict overview (Dr C. Howard-Williams, DSIR and NIWA, 2016 interview).

These statements are consistent with one another. They suggest a largely bottom-up curiosity-based approach, driven by scientists with their own specific Antarctic research interests. They were also informed about the work being carried out in their field by Antarctic scientists from other countries through SCAR symposia and in formal collaborations, reducing pressure for the RDRC to develop a more coherent programme. The possibility of the research being useful to inform policy or to solve problems had not yet arisen. Publication of the research results was seen as a sufficient end point.

There were only rare interventions at the ministerial level, except when public sector costs were being cut generally, as happened in the late 1970s. Even in years when the DSIR's work was limited by funding cuts, the universities were able to continue with their field studies.

Key New Zealand science system developments

The 1987 STAC report and its outcome

In order to explain why the research has evolved since 1991 as it has, it is necessary to explain the context and in particular how the radical changes after 1984 that led to the dissolution of the DSIR and to the introduction of the current contestable funding system, and later changes to it, came about.

What follows is an overview that focuses on one key report. For a more detailed analysis, including of the organisational and personal interactions involved, see Palmer (1994).

Following a change of government in 1984, reform took place across all aspects of New Zealand's economy. A 'Fortress New Zealand' interventionist model was replaced by a neoliberal free market and principal-agent model. New Zealand was in the vanguard of developing many of these policies, though it also took note of what was happening elsewhere.

The Science and Technology Advisory Committee (STAC) report was a key document for changes to the science system (STAC, 1987). Nearly all of its recommendations were adopted. Its terms of reference included reviewing the adequacy of existing research funding mechanisms with respect to financial and economic measures of efficiency, and recommending appropriate options for changes in the organisation, structure and funding of science, including policy advice and operational responsibilities. Its key conclusions were:

- Control over public sector expenditure until 1984 had been over the inputs used, not the outputs generated. This was not financially efficient or in line with best international practice.
- Contestability should be the governing principle for the allocation of research funds. The universities should be able to participate in Vote: Science contests.
- Determining the aggregate level of funding should remain a political decision. Government should only fund non-appropriable science. The focus should be on environmental, public good, training and pre-commercial work. End-users should pay for most applied science.
- The DSIR had an unresolvable conflict of interest between its role as adviser to the minister and being a science provider. The DSIR, Ministry of Agriculture and Fisheries and other public sector science activities should be merged and restructured into a series of

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stand-alone enterprises, with no ministerial advisory functions. These became the CRIs.

- Broad research objectives and funding criteria should be decided by a new MoRST. This should also be the primary source of science policy advice to the minister, but should have no involvement in funds allocation or science provision.
- Funding decisions should be delegated to a National Research Council with an independent board. It should be given clear and detailed objectives, be audited and report annually to parliament. This became FRST. In practice, Simon Upton, the Minister for Science after 1990, wanted some contestability in the provision of policy advice, so FRST's Act allowed for this. FRST was also made responsible for developing detailed research objectives, funding criteria and for preparing the investment signals for each funding round. It managed the bulk of Antarctic science funding. Its 1990s contests 'were fairly gentle, as most programmes were well-established, long-running and produced good research' (Dr C. Webb, FRST's operations manager 1995–2001, 2015 interview).
- Peer consultation and review was not sufficient for funding decisions. This risked capture of the process by scientists. Applicants needed to be given clear advice. Sound criteria were needed. Contests needed to be transparent. It was important to foster local and overseas collaborations.
- The threat of reform meant that most scientists believed that funding for their speciality was at risk. Morale was low. They needed certainty as to what would change. Government also needed to improve the low esteem in which science was held by the New Zealand public.

A national government was elected in 1990. It added some non-contestable output funding, so as to provide some medium-term stability for those who work in research institutions, without reinstating the luxury of vote funding divorced from performance (Upton, 1990). The DSIR and other research agencies became ten (now seven) CRIs in 1992.

In 1995, Vote: Science funding was opened to universities and others, and public funding of appropriate research was allowed when it could be shown that it was of national benefit but there was a provable failure of the market to provide it.

The 1992 DSIR Antarctic Division's transfer and MFAT's ongoing involvement

The DSIR's Antarctic Division policy team transferred to MFAT in 1992. It was argued that this would strengthen MFAT's dealings with the ATS members and support the New Zealand/USA Antarctic relationship (S. Prior, ex-Head of MFAT's Antarctic Policy Unit, 2016 interview). MFAT convenes a Senior Officials Committee that meets periodically on Antarctic policy (but not detailed science) issues. MFAT's stated view (MFAT, 1996) was that New Zealand's Antarctic interests would best be promoted by active and responsible stewardship for present and future generations, by:

- Maintaining a long-term interest in and commitment to the Ross Dependency.
- Keeping Antarctica as a neutral and non-aligned neighbour.
- Enhancing New Zealand's economic opportunities within the parameters of the ATS.
- Enhancing New Zealand's leadership in the governance of Antarctica.
- Promoting Antarctica as a natural reserve devoted to peace and science.

The 1996 establishment of AntNZ

In 1991, the RDRC's Chair, Bob Norman, who had been Commissioner of the Ministry of Works and Development until it was privatised in 1988, wrote strongly to the Minister of Science, Simon Upton:

> A great deal of effort has gone into considering the future of New Zealand's Antarctic programme and thus the future of the RDRC and DSIR's Antarctic Division. I am bound to say that the process of arriving at a consensus among interested parties to enable you to be given a firm recommendation has been an exercise in futility. What needs to be understood is that it is not possible to use the interdepartmental consensus model as a means to rationalise an inter-agency management process which has operated very successfully, with clear guidelines, for over 30 years… Some of the submitted recommendations are quite unacceptable in the view of my committee with its long experience of running the programme. If adopted, we are in no doubt that the programme and its management would be put seriously at risk (DSIR, 1991).

The minister had proposed removing two-thirds of the funding that had been in FRST's ring-fenced Antarctic research fund and reassigning it to general environmental research funding, but with no intention of cutting Antarctic funding overall (S. Upton, personal communication, 2016). He kept Antarctic funding separate, but still went ahead with the broader science system changes.

Sir Robin Irvine, the final RDRC Chair, grew frustrated with how the RDRC worked. He wanted logistics and science funding decisions to be better combined. He agitated with MFAT for the creation of a New Zealand Antarctic Institute to achieve this. When this was created as a Crown Entity in 1996 (after a battle with the Treasury, which wanted it to be a company), it quickly renamed itself AntNZ. The New Zealand Antarctic Institute Act (1996) details its functions as: to develop, manage and execute New Zealand activities in respect of Antarctica and the Southern Ocean, in particular the Ross Dependency; to maintain and enhance the quality of New Zealand Antarctic scientific research; and to cooperate with other institutions and organisations both within and outside New Zealand having objectives similar to those of the Institute.

Sir Robin became its first Chair (S. Prior, ex-Head of MFAT's Antarctic Policy Unit, 2016 interview).

The 2012 creation of MBIE

In November 2010, FRST and MoRST were merged into a new Ministry of Science and Innovation (MSI). In July 2012, MSI in turn became a small part of the newly created MBIE, which has had a strong economic goal emphasis (rather than an environment, social or knowledge focus). The remaining policy personnel from MoRST nearly all left, taking with them much of the corporate memory and detailed science system knowledge. This change was made with little science system stakeholder consultation, at the behest of Steven Joyce, who in 2012 became the Minister of Tertiary Education as well as of MBIE.

The 2012 creation of NZARI

The NZARI was set up in 2012 as a charitable trust, largely at the instigation of Sir Rob Fenwick, a widely respected and influential businessman, who became its founding Chair. It runs small Antarctic research funding rounds, with new funding primarily from the philanthropic private sector Aotearoa Foundation, Air New Zealand and, more recently, *National Geographic*.

NZARI is in an unusual position. It is a non-government organisation, with no direct influence over other funding agencies, ministries or research organisations, yet its director has, since 2012, been on the senior management team of AntNZ as its Chief Science Advisor. AntNZ is responsible for Antarctic logistics, including for NZARI's projects, and pays the salaries of NZARI's two other staff. Several of the author's interviewees have argued (non-attributably) that this is a conflict of interest.

The Deep South national science challenge

The Deep South national science challenge is one of 11 national science challenges arising from a government initiative to focus research on issues of wide public concern and significance (New Zealand Government, 2014). Effectively, it is an interdisciplinary collaborative research consortium, 'a lightning rod for useful science' (Dr E. Butler, MBIE, 2016 interview). It is supporting additional sea ice and Southern Ocean research, with around $0.6 million per annum of new funding. The CRIs were instructed to realign their research priorities and discretionary funding to support its goals, which is why NIWA rather than NZARI coordinates it. One impact has been to refocus research to some extent away from the continent.

Planning and review documents produced since 1991

Other than for the first seven years of AntNZ's existence, 1997–2004, there has been no detailed review made of New Zealand's Antarctic science achievements since 1991, so analysis of this period relies on published planning documents, strategies and one detailed evaluation.

The RDRC's 1993–1998 plan

The RDRC's final five year plan, for 1993–1998, was produced in consultation with FRST (RDRC, 1993). It stated that the RDRC emphasised research purpose and relevance, so as to support the protection of the Antarctic environment and other national interests and international obligations by developing an understanding of the nature, evolution, environment and unique life forms of Antarctica, and, in particular, the Ross Dependency and its surrounding sea. The plan focused on four priority themes, with all programmes to be judged with respect to the quality and relevance of the work proposed and the qualifications, skill and experience of the researchers:

- Climate processes: the atmospheric processes driving global and hence New Zealand's climate changes; and the impacts of human-caused pollution, greenhouse gases and ozone depletion.
- Terrestrial evolution: the geological evolution of the margin of Antarctica that juxtaposed New Zealand 80 million years ago, and the subsequent evolution of the Ross Sea.
- Human activities: the human strain on the Antarctic atmosphere, ocean and terrestrial environments over the coming decades could have severe impacts and needed study.
- Biodiversity: physiological and cellular biology, with more international collaborations, such as the US-led Long-Term Ecological Research programme in the Dry Valleys and SCAR's Biological Investigations of Terrestrial Antarctic Systems programme.

It also suggested more research into tourist activity impacts and into developing improved environmental protection measures. However, the plan did not list funding decision criteria or describe how best to allocate funding among the four priority themes.

AntNZ's 1998–2003 and 2004–2009 strategies

AntNZ produced its first science strategy for Antarctica and the Southern Ocean in 1998 (AntNZ, 1998). This had five broad themes, each with a set of associated outcomes, which were further expanded by setting key questions for each outcome. It gave no hint as to how progress might be measured but did include some useful criteria as to how Antarctic research proposals should be prioritised, including:

- Science should be of internationally reputable scientific merit.
- Programmes should need information best obtained only from Antarctica or the Southern Ocean because of the high cost of supporting research there.
- The work should contribute to the world's store of scientific knowledge and understanding.
- Research should contribute to the outcomes of the five broad research areas and provide scientific, economic and/or environmental benefits to New Zealand.

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- Research should support New Zealand's international interests and obligations.
- Research should be carried out in significant partnerships with other nations or form part of a formal international research programme.
- Research must have minimal impact on the natural environment.

FRST applied this strategy in its later contests and used AntNZ as its reference panel for its Antarctic research funding contests. Quantitative measures were rarely available but the criteria were clear.

AntNZ's 2004 update had three broad priority research themes:

1) Antarctic physical environments (six sub-themes)
2) The Southern Ocean (five sub-themes)
3) Antarctic ecosystems (four sub-themes).

Three to six key questions were proposed for each sub-theme. No outcomes were defined. No measures as to what success would look like were set, and so virtually any research proposal could be made to fit somewhere. This was not much help for prioritisation.

AntNZ's 2005 evaluation

In 2005, AntNZ convened a panel to assess the science it had supported from 1997 to 2004. The panel of five, which included two Australians, an American and two New Zealanders, was asked to review all the science supported over this period and to take a view on New Zealand's Antarctic research capabilities and gaps, so as to help the future prioritisation of Antarctic and Southern Ocean research.

Its report listed 808 publications (588 journal articles, 87 chapters in books, 54 publications in proceedings, 21 books, 38 theses and 20 reports) and all the journals involved, but did not divide the work up by discipline (AntNZ, 2005, pp. 40–60). It focused on work on:

- The atmospheric science in and related to Antarctica and the Southern Ocean.
- The understanding of sea ice and climate-related sea ice changes.
- The stratigraphic history of the Antarctic littoral and sheet ice.
- The marine biology and ecology of Antarctica and the Southern Ocean.

It noted that relatively regular publications in *Nature* had highlighted New Zealand leadership in some areas. It used bibliometric and impact factor analyses to conclude that both the 'small science' and 'targeted science' sides of New Zealand's programme were of international standard. It also noted that some excellent technologies had been developed for investigations in the Antarctic.

The evaluation commented on the complexity of the funding processes, with four possible funding routes and multiple committees. It recommended that an Antarctic Science Integrating Committee (ASIC) be formed as a central coordinating body, with a mandate extending to all New Zealand Antarctic research. It also recommended that another similar evaluation be undertaken in 2010 in relation to integration of outcomes from small programmes and the division of support between 'curiosity-driven' and 'targeted' programmes. Neither of these recommendations has been acted upon.

It also suggested more collaboration in areas of importance to New Zealand, such as with CCAMLR and the International Whaling Commission (IWC).

It included (AntNZ, 2005, p. 39) a table of overall funding from 1997/1998 to 2004/2005, which showed that the science funding totals more than doubled during a period in which price inflation rose by 13%. It would be useful for an update of this table to be prepared and made public.

Antarctic and Southern Ocean science directions, 2010–2020

In 2011, the New Zealand government endorsed a new Antarctic research strategy, 'Antarctic and Southern Ocean science directions, 2010–2020', after a period of public consultation (New Zealand Government, 2011). It is a good example of setting directions and values so that the outputs and outcomes achieved can be measured.

The document was a collaborative effort between MFAT, the Ministry of Fisheries, the short-lived MSI and AntNZ. It focused on the types of Antarctic research seen as being most valuable. It required all of New Zealand's public sector science funding sources, other than the untargeted Marsden Fund, to align with the framework. Enforcement of this was to be through AntNZ's control over logistics funding on the continent.

Its three broad areas cover: (1) climate, cryosphere, atmosphere and lithosphere; (2) inland and coastal ecosystems; and (3) marine systems. These are all set within a unifying and overarching theme of global change to help understand and manage human impacts in Antarctica. For each outcome, three to five research goals are defined, New Zealand's potential contribution to the global effort is explained and how New Zealand's work will link with SCAR and CCAMLR priorities and why this matters are outlined, and measures as to how we will know that we are delivering on each outcome are laid down.

National and international collaborations are emphasised, so as to:

- Assemble world-class and interdisciplinary teams.
- Help programmes to reach a critical mass, such as for ship-based marine research.
- Assist in the dissemination of findings to a wider audience.
- Help upskill researchers and expose scientists to different approaches.
- Share the costs of science and logistics to assist with building international links and relations.

This is a considerable improvement on AntNZ's 2005 strategy. It is more tightly focused, which enables better

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prioritisation, and it has good progress measures. Unlike most previous strategies, it does not focus mainly on science disciplines. The only significant adverse comment the author received from some interviewees is that it perhaps overemphasises biological research, which comprises the second and third of the three main themes. This strategy is currently being updated.

AntNZ's 2013–2016 Statement of Intent

In 2013, AntNZ released a Statement of Intent. This included a chart showing that New Zealand researchers published an average of about 75 Antarctic research papers annually from 2004 to 2012. It also included some positive data on New Zealand's influence with ATS members. It stated:

> Dudeney & Walton (2012) used counts of policy papers and science publications to assess the political and scientific outputs of all Antarctic Treaty Consultative Parties over the period 1992–2010. In terms of the total sum of Working Papers submitted over this period, New Zealand rated second, with the UK first. When comparing the production of (influential) Working Papers with (background) Information Papers, the authors found that only four countries showed a positive balance in favour of Working Papers: New Zealand, France, Norway and the UK. A simple count of all Measures, Decisions and Resolutions initiated by each Antarctic Treaty Party shows New Zealand to be third behind the UK and the US (AntNZ, 2013).

International collaborations

One reason why New Zealand is influential is the quality of the policy papers New Zealanders have contributed to ATS meetings (Dudeney & Walton, 2012). Others include the reputation and output of its Antarctic researchers, who have participated in numerous international research collaborations. Several New Zealanders have also made significant administrative contributions, for example George Knox as President of SCAR 1978–1982, Chris Beeby on the development of the CRAMRA 1982–1988, Gillian Wratt as Chair of the Council of Managers of National Antarctic Programmes (COMNAP; which is based in Christchurch) 1998–2002, Neil Gilbert as Chair of the Committee for Environmental Protection (CEP) 2006–2010, and three SCAR Vice-Presidents: Fred Davey 1998–2000, Clive Howard-Williams 2002–2006 and Bryan Storey 2012–2016.

By far the most important international partner for New Zealand in Antarctica has been the USA (Peat, 2007). The two countries share logistical arrangements, based in Christchurch. The McMurdo Station and Scott Base are only 3 km apart. This close Antarctic relationship began before Scott Base's site at Pram Point on Ross Island was chosen. It has persisted. Two knowledgeable interviewees asked by the author to comment on the New Zealand/USA relationship replied:

> Collaboration with Americans is largely through personal contacts. Most collaborations have worked well, due to inherent American generosity. They have been well resourced. They value New Zealanders as being original, competent and not competitive within the United States science system, so they are open to working with us (Dr F. Davey, DSIR, GNS, 2015 interview).
>
> During the 1990s, MFAT saw collaboration with the Americans in Antarctica as politically essential, as the one positive engagement left after the 1984 ANZUS row, and also because of the Christchurch infrastructure. The United States reciprocated and wanted to keep on collaborating (Dr S. Devine, DSIR, FRST from 1991–1995, 2015 interview).

In recent years, climate change and global warming scenarios have motivated an array of joint projects with the USA and other countries. The Ross Sea, at the tectonic border between East and West Antarctica, has provided excellent sites for investigating past climate events, which help throw light on what may be in store for the globe in the centuries ahead. The biggest palaeoclimate drilling project has been ANDRILL (ANtarctic Geological DRILLing), a collaboration between the USA, New Zealand, Italy and Germany. Its original goal was to core sediments laid down over the past 20 million years, complementing the multinational Cape Roberts drilling project, which in 1997–1999 drilled cores covering the period 17–34 million years ago. ANDRILL cored two holes from 2007–2009 very successfully from floating ice platforms, each at a depth of over 1,000 m (Barrett, 2009). However, although a consortium of six countries led by New Zealand, with the USA, Italy, Germany, South Korea and Brazil, proposed further deep drilling for older climate history east of Ross Island, the US NSF recently declined to support it, on account of logistical constraints. There is a broad consensus that the scientific and technological achievements from the past four decades of ANDRILL and the previous drilling projects have been excellent. New Zealand researchers have achieved a very high global reputation in this area.

Many AntNZ sponsored projects involve international collaboration. There was a general boost in collaborative activity for the 2007/2008 IPY. Recent examples have included:

- Sea Ice Programme (1980, ongoing), based at the University of Otago, studying sea ice processes in McMurdo Sound.
- The Latitudinal Gradient Project (2002–2011), a framework involving land, freshwater and marine ecosystem scientists that ranged from Cape Hallett to Beardmore Glacier.
- International Centre for Terrestrial Antarctic Research (ICTAR; 2013–ongoing), based at the University of Waikato, dedicated to understanding the Antarctic terrestrial environment.

- The ANDRILL project (2006–2008), recovering glacial history of the last 20 million years in two deep cores from McMurdo Sound.
- The Roosevelt Island ice Coring Expedition (RICE) (2013–2015), a high resolution record of climate history covering the last 70,000 years.
- The Ross Ice Shelf programme (2014–2018), a multidisciplinary project investigating ice shelf vulnerability through glaciological and oceanographic investigations.
- Marine ecosystem research (ongoing), ongoing programmes by NIWA studying the Ross Sea ecosystem, including possible effects on the toothfish fishery and on the coastal ecosystem.

Other significant ongoing work includes ozone depletion and atmospheric chemistry studies at Arrival Heights and geophysical and climate observations at Scott Base, as part of a global network.

SCAR's priorities

SCAR recently agreed on six key priorities for Antarctic research over the next two decades and beyond, and has called for greater collaboration and environmental protection in the region. SCAR narrowed the priorities down to six, from a longer list of 80 pressing questions (Kennicutt et al., 2014). New Zealand researchers have established strong reputations in most of these areas:

1) Define the global reach of the Antarctic atmosphere and Southern Ocean through better understanding of the underlying processes and interactions for heat, carbon dioxide and nutrient transfers, ocean acidification and sea ice formation and melt.
2) Understand how, where and why ice sheets lose mass, as that will be key to predicting how fast sea levels will rise.
3) Reveal Antarctica's history through ice, rock and sediment records. (The Ross Sea, where the two Antarctic plates meet, is the best place to do such coring work and is in New Zealand's 'patch').
4) Learn how Antarctic life evolved and survived, through genomic, molecular and cellular studies.
5) Use Antarctica as an astronomical observation platform and astrobiology laboratory.
6) Recognise and mitigate human influences, so as to improve governance and regulation.

Conclusions

Overall, much of New Zealand's Antarctic research has achieved a high international standard. The range of international research collaborations is a reflection of the high global regard in which many New Zealand researchers are held, but this is to some extent despite the system not because of it. New Zealand has also been a significant contributor of policy papers and personnel to the ATS, SCAR, COMNAP and other Antarctic organisations.

Before 1991, the organisational model can be seen on balance as dominant. The relevant organisations were all represented on the RDRC, which fell under the aegis of the DSIR. The DSIR was happy to share. There is little evidence of game playing, other than members naturally seeking support for their own research.

However, there were no criteria for choosing projects other than a loose science merit overview, political acceptability and logistical affordability. The extent of the activity was determined by the cost of inputs rather than the value of measurable outputs. There was no attempt to quantify benefits. This was typical of the time. In addition, early work plans were little more than lists of research disciplines. The first widely circulated research strategy did not appear until 1985. The first research evaluation was not made until 1988. Nevertheless, New Zealand scientists developed their own international networks, establishing key lines of research and an overall strong reputation abroad.

There is considerable evidence that the rational decision-making approach has become increasingly dominant since 1991 in funding decisions, research strategies and evaluations, for example:

- Funding criteria are well-defined. The contests are widely accepted as fair and transparent.
- The 2005 evaluation reached positive conclusions, especially in terms of science excellence.
- The quality of the research strategies has improved in terms of defining the outcomes sought and in developing appropriate quantifiable measures of progress towards them, rather than simply in terms of science disciplines, with no prioritisation.
- International collaboration has become the norm. This is cost-effective for all involved.

Since 1991, the introduction of contestability has eliminated some programmes that had reached the point of diminishing returns, though there are still areas of research that have persisted since 1957/1958. These are justified on modern criteria and through the use of new techniques and equipment.

From 1991–2010, FRST was the main source of funding for the CRIs. According to several of those interviewed and the author's own experience, it did not always fund the proposals that the CRIs themselves believed to be the most important, or all of the interlinked projects needed to optimise an ongoing programme of work. For Antarctic research contests, some participants query whether FRST always struck the best balance between biology, earth sciences and other disciplines, or between large programmes and individual curiosity-driven projects.

With respect to university research, FRST contests became a key funding source after 1995. Most of their other funding is sourced from the TEC, which has little direct influence over how its funding is used by the university departments that receive it. The Marsden Fund, NZARI, Deep South and other sources are also important to some researchers.

Recent research strategies involving AntNZ have been done well, especially the 2010–2020 strategy. Its update should include evidence collected on the 2010–2020 outcome progress measures. The 2005 evaluation should also be replicated, with an analysis using citation data of New Zealand Antarctic publications since 2004 and an update of the funding by source and year since then.

Research funding for Antarctic research now comes from more sources than for any other part of New Zealand's science system. The separate funds are all relatively small and are poorly coordinated. Some degree of rationalisation is warranted. Pooling would improve efficiency and effectiveness; however, some researchers like the funding fragmentation and the ability to apply to multiple sources.

New Zealand should seek to ensure that its research priorities in Antarctica support an understanding of its own environment and that they contribute to better understanding of the global environment. Antarctic science priority setting needs to take account of both national and global priorities. A strong evidence base is crucially important if science is to influence global policymakers. New Zealand researchers are well placed to continue contributing to this evidence base, thereby informing the global debate on how best to react to climate change and on other key issues.

The bureaucratic politics model is the best explanation for some of the structural system change decisions since 1991 and especially since 2010. Individuals have at times sought and sometimes gained positions of power by successfully playing games. Ministers have forced through system changes with little true consultation.

> Strong personalities and people with their own agendas have driven most structural changes (Dr B. Walker, DSIR policy team and MoRST's first Chief Executive, 2016 interview).

In the author's view, some of these changes risk weakening the international standing of New Zealand's Antarctic research. To create and retain world-class research teams, a measure of stability and continuity is highly desirable. A system needs to be stable long enough for sufficient data to be collected for an evaluation to be able to show whether the last set of changes has increased or instead reduced value. Several interviewees are especially critical of MBIE's current lack at the senior policy level of knowledge of the science system and of its culture, and of the rationale for past decisions.

Over the past 20 years or so, AntNZ has done its best to advise on and to coordinate continental Antarctic science activities. Its success has been largely due to a few key individuals. There is no guarantee that future coordination will be managed as well. It has yet to fulfil its potential as an effective 'one-stop-shop' coordinating body. The role of the NZARI in connection with it needs clarification.

Finally, Antarctic-related activities have a material economic impact in New Zealand. Christchurch is a key gateway city to the continent. The USA, Italy, South Korea and China all base at least part of their Antarctic logistics operations there. Research and logistics support totalled $80 million in 2014/2015, with an additional $98 million sourced from tourism, fishing and heritage activities. Antarctica directly and indirectly supports over 6,800 New Zealand jobs (Saunders, Guenther, & Dalziel, 2016). These numbers have risen in inflation-adjusted terms since Saunders and colleagues wrote reports on a similar basis in 2007 and 2013. In addition, their 2016 report stated that a substantial upgrade of Scott Base is currently under discussion. Undertaking this would imply making a long-term commitment to land-based Antarctic research and would help secure and maintain public awareness of and pride in New Zealand's achievements on the continent.

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- Dr Edward Butler, FRST, AntNZ, MBIE – February 2016
- Dr Clive Howard-Williams, DSIR, SCAR, Chief Science Adviser NIWA – February 2016
- Dr Dean Petersen, ex-AntNZ – February 2016

No-one who was asked to give an interview refused. The author acknowledges that many others might well have been able to add pertinent and interesting comments. However, as none of the interviewees contradicted one another, and the line had to be drawn somewhere, these

have sufficed. The interviews were free flowing rather than proceeding from a fixed list of questions, as the time periods covered and the policy and/or scientific backgrounds of the interviewees varied enormously. The author's own background was as Chief Policy Adviser at FRST from 2000–2004 and Principal Policy Adviser at MoRST and its successors from 2004–2006 and 2010–2013.

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References

Allison, G.T. (1971). *Essence of decision: explaining the Cuban missile crisis*. Boston: Little Brown & Co.

AntNZ (Antarctica New Zealand). (1998). *New Zealand science in Antarctica and the Southern Ocean (1998–2003)*. Christchurch: Antarctica New Zealand.

AntNZ (Antarctica New Zealand). (2004). *New Zealand science in Antarctica and the Southern Ocean (2004–2009)*. Christchurch: Antarctica New Zealand.

AntNZ (Antarctica New Zealand). (2005). *Report of the review committee on New Zealand's Antarctic science*. Christchurch: Antarctica New Zealand.

AntNZ (Antarctica New Zealand). (2013). *Statement of Intent 2013–2016*. Christchurch: Antarctica New Zealand.

Barrett, P. (2009). A history of Cenozoic glaciation – view from the margin. *Developments in Earth and Environmental Science*, *8*, 33–83

Brady, A.M. (Ed.). 2012. *The emerging politics of Antarctica*. Abbington: Routledge.

DSIR (Department of Scientific and Industrial Research). (1983). *Antarctic achievements 1957–1982: New Zealand's role in the Antarctic*. Wellington: Department of Scientific and Industrial Research.

DSIR (Department of Scientific and Industrial Research). (1988). *Antarctic science – science activity review no. 1*. Wellington: Department of Scientific and Industrial Research.

Dudeney, J. R., & Walton, D. W. H. (2012). Leadership in politics and science within the Antarctic treaty. *Polar Research*, *31*, 11075.

Kennicutt, M. C., Chown, S. L., Cassano, J. J., Liggett, D., Massom, R., Peck, L. S., . . . Sutherland, W. J. (2014). Six priorities for Antarctic science. *Nature*, *512*, 23–25.

Lindblom, C. E. (1979). Still muddling, not yet through. *Public Administration Review*, *39*, 517–526.

March, J. (1965). *Handbook of organisations*. Chicago, IL: Rand-McNally.

MFAT (Ministry of Foreign Affairs and Trade). (1996). *Information bulletin 59*. Wellington: Ministry of Foreign Affairs and Trade.

Morten, P. D. (2006). *National benefit and its application to publicly funded research, science and technology investment*. Wellington: Ministry of Research, Science and Technology.

New Zealand Government. (2011). *Antarctic and Southern Ocean science directions 2010–2020*. Wellington: New Zealand Government.

New Zealand Government. (2014). *The Deep South national science challenge*. Wellington: New Zealand Government. Retrieved from www.deepsouthchallenge.co.nz

Nossal, K. M. (1979). Allison through the Ottawa looking glass. *Journal of the Canadian Public Administration*, *22*, 610–626.

Palmer, C. M. (1994). *The reform of the public science system in New Zealand: a history of the background to and the implementation of the restructuring of the science system, 1988–1993*. Wellington: Ministry of Research, Science and Technology.

Peat, N. (2007). *Antarctic partners: 50 years of New Zealand and United States cooperation in Antarctica 1957–2007*. Wellington: Phantom House Books.

Quartermain, L. (1971). *New Zealand and the Antarctic*. Wellington: New Zealand Government.

RDRC (Ross Dependency Research Committee). (1959). *Report to SCAR on New Zealand's IGY results*. Wellington: Ross Dependency Research Committee.

RDRC (Ross Dependency Research Committee). (1959–1991). *Annual reports attached for 32 years to the annual reports of the Department of Scientific and Industrial Research*. Wellington: Department of Scientific and Industrial Research.

RDRC (Ross Dependency Research Committee). (1985). *Future directions in New Zealand Antarctic research*. Wellington: Ross Dependency Research Committee.

RDRC (Ross Dependency Research Committee). (1993). *1993–98 Antarctic research plan*. Wellington: Ross Dependency Research Committee.

Saunders, C., Guenther, M., & Dalziel, P. (2016). *The contribution of Antarctic-related activities to the Canterbury and New Zealand economy*. Lincoln: Agribusiness and Economics Research Unit, Lincoln University.

STAC (Science and Technology Advisory Committee). (1987). *The science and technology advisory committee report*. Wellington: Science and Technology Advisory Committee.

Simon, H. (1957). *Administrative behaviour* (2nd ed.). London: Macmillan.

Stern, N. (2006). *Stern review: the economics of climate change*. London: H.M. Treasury

Upton, S. (1990). National's policy on science, research and technology. *New Zealand Engineering Journal*, *45*, 35–37.

Walton, D. W. H., Clarkson, P. D., & Summerhayes, C. P. (2011). *Science in the snow: fifty years of international collaboration through the Scientific Committee on Antarctic Research*. Cambridge: Scientific Committee on Antarctic Research.