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The Value of Antarctic Research

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Abstract

This report examines the value of Antarctic research from several different perspectives. The values of those working in Antarctica are considered, as is the value of Antarctica itself. Antarctica is seen to be one of the last wilderness areas of the world. This alone gives Antarctica intrinsic value. The importance that this ecosystem has to the rest of the planet, as a driver of sea currents and atmosphere, gives Antarctica a high value to all peoples of the world, especially to the scientists who conduct research there. The values of all the stakeholders involved in Antarctic research are important to consider, as they motivate the actions of the future.

A further perspective of the value of Antarctic research can be given by assessing the research achieved. Although existing metrics have known flaws to consider, assessment of Antarctic research has provided valuable information on trends in research, the productivity of different researchers, organizations, and countries, and influence within the Antarctic Treaty System, (ATS). New measures of assessing research can help broaden the scope of impact, and lead to greater recognition of the value of the overall intellectual contribution of Antarctic research.

As there are a large range of stakeholders who have an influence on Antarctic research, it is important to examine how each different set of values plays out in an Antarctic context. The values which stakeholders hold influence governance decisions as well as defining the focus of Antarctic research. They are therefore important to consider. Because of the large number of stakeholders and the values at play, the whole system is dynamic.

This report also looks at the political worth and economic value of Antarctic research. Science and collaboration are the currency of diplomacy in Antarctica. They serve New Zealand's and many other governments' aims well. Especially for small nations, working within an effective rules-based system such as the ATS is the best way of influencing others.

The main economic value added of Antarctic science generally is likely to be through helping to minimise the impacts of climate and other human-induced global environmental changes. Marine resources and tourism are also significant but mining land-based minerals is unlikely while the ATS and its Protocols remain in force.

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The Value of Antarctic Research

Introduction

The purpose of this report is to assess the value of Antarctic research. We begin by examining the meaning of value, both as a value assigned to an object and the values that each person lives by. Both of these types of value can motivate actions.

People can hold an object as so valuable that they would not trade it or sell it at any price. This is the object that, if you had to leave your house quickly in the face of some disaster, you would take it with you at the expense of all other things. Considering Antarctica to be the object, in this report we suggest that the values assigned to Antarctica by the Protocol on the Environmental Protection to the Antarctic Treaty, also known as the Madrid Protocol, that specify Antarctica as a wilderness with aesthetics and scientific value, need to be clearly defined in order to be protected, which is the intention of the Protocol. Article 3 of the Treaty states that the protection of the Antarctic environment as a wilderness with aesthetic and scientific value shall be a "fundamental consideration" of activities in the area (Wikipedia). A more accurate definition of these values, and of the motivational and value systems of different stakeholders in Antarctica, will assist in assigning value to Antarctica and to the scientific research carried out there.

Motivational types of Values

Definitions of motivational types of values in terms of their goals and the single values that represent them. Shalom Shwartz (2013) has isolated the values set out in the table below as the main motivational values of human behaviour.

Table 1. Schwartz, S (2013) "Value Priorities and Behaviour, Applying the Psychology of Values" The Ontario Symposium Vol 8 Psychology Press.

Power	Social status and prestige, control or dominance over people and resources.
Achievement	Personal success through demonstrating competence according to social standards.
Hedonism	Pleasure and gratification for oneself.
Stimulation	Excitement, novelty, challenge in life.
Self-direction	Independent thought and action, choosing creating and exploring.
Universalism	Understanding, appreciation, tolerance and protection for all people and for nature.
Benevolence	Preservation and enhancement of the welfare of people with whom one is in frequent contact.
Tradition	Respect, commitment and acceptance of the customs and ideas that traditional culture or nature provide.
Conformity	Restraint of actions, inclinations and impulses likely to upset or harm others and violate societal expectations or norms.
Security	Safety, harmony and stability of society, of relationships and self.

These individual motivational value systems will be held by an individual within their own cultural and organizational value systems.

Values that have changed over time

The heroic era in Antarctica had specific goals that involved exploration, mapping, flag planting and scientific research. Magnetism, geology and discoveries of new flora and fauna were valued. The early explorers were prepared to risk their lives to collect data. An example of this is the lengths that Scott and his party took to carry fossilized trees and other heavy rock samples on their sledges on their ill-fated return back from the South Pole in 1912. Values held by the early explorers certainly included holding the character of the men they journeyed with in high esteem. Aristotle, a Greek philosopher and scientist who live between 382 and 322 BC, argued that ethical theory, or moral philosophy, was a separate theory to that of theoretical sciences. Aristotle determined that the development of character meant the ability to do the right thing at the right time in the right way "We are what we repeatedly do. Excellence, then, is not an act, but a habit."

Wildlife in these early expeditions was seen as a food source for dogs and men or as a specimen that could be harvested for a museum exhibit. Values held are most obvious when conflict or crisis arises. The measures taken of careless waste disposal and wildlife harvesting were seen as expedient for survival and the achievement of goals.

The motivational values in the early part of the 20th century are largely similar to those of the scientists working in Antarctica today, although the values of universalism, protection of nature, tradition and conformity are perhaps different now. These different values are able to be moderated, as the crisis of survival against the odds in an extreme environment are not as ever present as it was for the heroic era explorers. "They coped with hunger, hidden crevasses, frostbite and exhaustion and were given the well- earned hero's welcome on their return," wrote Sir Douglas Mawson on his return from a sledging journey of 122 days with Professor Edgeworth David as members of Shackleton's 1907-1909 British Antarctic Nimrod expedition.

As our awareness of the global environment has changed and as we have found ways to work and live in Antarctica with increased comfort, we have adapted our value system in Antarctica. Societies continue to adapt to political, economic, military, climatic, technological and other changes in the environment. (Schwartz, 2012).

The reasons that a scientist may choose to conduct research in Antarctica may be determined by his or her motivational values. An individual may decide to take on a challenge such as science research in Antarctica based on their own self-belief. Eccles et al argue that the motivation to take on new challenges is based on:

1. Beliefs about competency and expectancy for success;
2. Achievement values;
3. intrinsic and extrinsic motivation;
4. Expectancy and value constraints; and
5. Motivational processes (Eccles and Wigfield, 2002).

An individual's belief in their own competence and their expectancy for success will be their motivation to select a more challenging task. (Schwartz). Deciding whether or not to conduct research in Antarctica may for many scientists reflect a positive value towards Antarctica as an object of intrinsic value. Intrinsic motivation can also be linked to a positive emotional experience (Matsumoto and Saunders, 1988). When people feel competent and self-determined, intrinsic motivation is maintained.

Value sets of different countries working in Antarctica

A set of values or value system can be defined as a set of connected or interdependent values (Eccles and Wigfield, 2002). These values can be expressed in different ways by different countries, cultures and religions.

Sacred values can be held by a culture or people. They cannot be bargained with. These values differ from material or instrumental values in that they incorporate moral beliefs that drive actions in ways that are disassociated from prospects of success (Carmichael et al, 1994). If a person was offered money to compromise these values, they would be insulted. Sacred values are those held by cultures or religions. They motivate actions. An understanding of another culture's values can be valuable in the area of diplomacy, where there is the possibility of compromise, giving recognition and acceptance of another's set of values. An example of this is the acceptance of the wearing of Jewish or Muslim headgear without restriction in western countries.

In the future, Antarctica's values may be challenged as countries are put under pressure by population growth, climate change and diminishing mineral resources. It will be important to appreciate other countries' value sets to further protect Antarctica, especially as the Madrid Protocol that states that "Any activity relating to mineral resources, other than scientific research, shall be prohibited."

Defining the value of Antarctica

In this report, we look at two surveys to ascertain the perception of the public of Antarctica.

There is an almost universal appreciation by the general public that Antarctica is of value because of the aspect of wilderness. It is the last untouched part of the planet, largely unpeopled, with research stations mainly around the coast. The protection of the wilderness and aesthetic values of Antarctica is undertaken by adhering to the Protocol on the Environmental Protection. To be able to protect these values, they must be defined. Values attributed to landscape may differ depending on the society viewing the landscape. An Inuit of Alaska may see a different landscape to a western or "first world" urban citizen.

The findings in a study by Summerson and Bishop (2012) and the value assigned to the landscape of Antarctica is from a predominantly western viewpoint.

Wilderness is defined by the US Wilderness Act, (1964), as an "…area that has outstanding opportunities for solitude or a primitive and unconfined type of recreation." Summerson and Bishop

conducted a survey asking people to view different photographs to show their perception of Antarctic wilderness. The survey showed that photographs of Antarctic landscape with no human presence or infrastructure gave the highest perception of wilderness. This was a survey where the respondents were mainly Australian and would be assumed to be giving a western, or "first world" perception of wilderness. Values of wilderness and aesthetics are closely linked. Perceptions of wilderness are almost always given a positively aesthetic value. Although aesthetic values are closely related to wilderness values, not all wilderness areas were seen as aesthetic. All of Antarctica can be regarded as a wilderness until it is degraded by human activity. According to this survey any anthropogenic infrastructure gives a perceived loss of wilderness. Landscapes with ice and snow were more highly rated as having aesthetic value than ice free Antarctic landscapes.

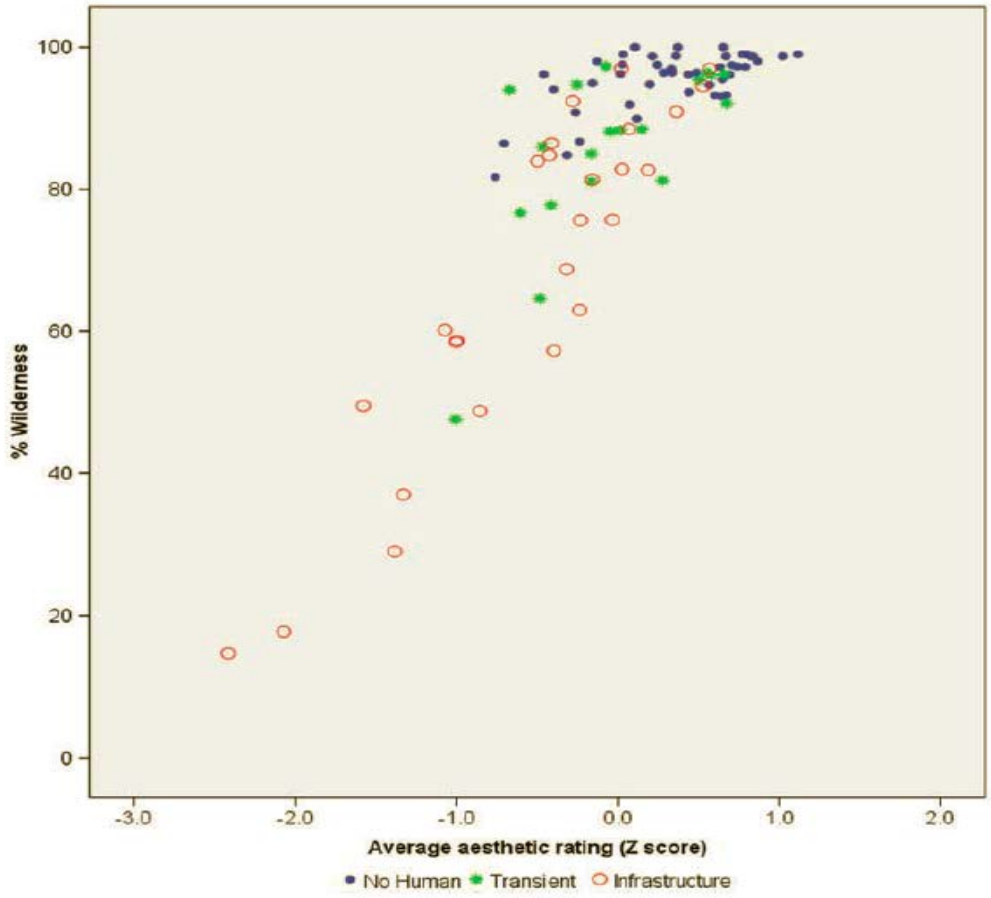

Figure 1. Scatter plot of averaged responses to wilderness and aesthetic values of 90 images. Perception of wilderness is expressed as a percentage of responses as wilderness to each image and aesthetic values as mean Z scores. (Summerson et al, 2012)

The second survey considered was conducted to gain further understanding as to how Antarctica is valued by the publics of different countries and among different ages (e.g. Students vs cruise ship tourists.) Developed from a set of common reasons that Antarctica can be valued as important, a meta-analysis was conducted, comparing the same values across nine different populations in Europe and North America between 2007 and 2012 (Bastmeijer and Tin).

These values included Antarctica's importance as:

1. A component in the Earth's climate system;
2. One of the world's last great wildernesses;
3. A science laboratory for the benefit of mankind;
4. A tourist destination;
5. A reserve of mineral resources that might support society in future;
6. An important environment for wildlife; and
7. An essential component in the history of human exploration

The findings of this survey compared the values held by the researchers who study Antarctica with those the values of the wider public, who are able to influence the policies and therefore are able to take action. Coexisting and conflicting values were also looked at.

Antarctic researchers were found to highly value Antarctica as a component of the Earth's climate system and as a last pristine wilderness and as an environment for wildlife. The value of a science laboratory was also valued highly. There was found to be a high correlation with the general public's values and the researchers. This is important, as common values will be a motivator towards fulfilling goals of further important research able to be carried out in Antarctica (Tin et al, 2013).

Defining the values of scientific research in Antarctica

Antarctica was designated an area of scientific value by the Antarctic Treaty in 1959 following the International Geophysical Year (IGY 1957-58). The Madrid Protocol set Antarctica aside as "… a natural reserve, devoted to peace and science." It further specified Antarctica as a wilderness with aesthetic and scientific value. We consider it important to examine the possible reasons why treaty signatories and scientists would assign value to their scientific research in Antarctica.

Scientists conducting research in Antarctica have perhaps a greater appreciation of the value Antarctica is as a place of scientific research. The reasons that each scientist is researching in Antarctica will be as a result of their own value set and the values of the organization that has enabled them to be in Antarctica. These values can vary across individuals, societies and over time, or they can be common. There are motivational values, as mentioned earlier in this report, held by the individual which may motivate the scientist to conduct research in Antarctica.

Ecosystem functions goods and services

Any ecosystem in the world can be seen as providing a function of goods and services. These goods and services are a way of valuing the ecosystem being examined. There is a Common International Classification of Ecosystem Services (CICES) (Biodiversity Information System for Europe) that can be applied to Antarctica.

Value assigned to the ecosystem of Antarctica are in the way of:

1. Provisioning; nutrition and energy. The Madrid Protocol protects Antarctica from being mined for resources. The only resources taken from Antarctica presently are Southern

Ocean toothfish and krill. Marine Protected Areas (MPA) are being negotiated to protect the delicate marine ecosystem.

2. Regulation and Maintenance and the mediation of waste. This is maintained in Antarctica by research stations themselves and is maintained and regulated by the Antarctic Treaty base inspections.
3. Cultural, physical and intellectual interactions with biota, ecosystems, atmosphere, land and water. The science conducted in Antarctica delivers valuable information about the Southern Ocean and the influence it has on the world's seas. Information can be gained about the world's atmosphere by examining the atmosphere above Antarctica.

The value of scientific research carried out in Antarctica is of value when it is taken back to the organization that initiated the science research. The data and findings are increasingly shared as common data throughout the world, as an appreciation of the need to see the world as a global system of sea and atmosphere is realized. As example of the value of Antarctic research is that the effects of climate change are able to be monitored in Antarctica by looking at the warming and freshening of the seas and by the changes in the sea ice. As the information is increasingly widely distributed this reliable knowledge can be used to make informed decisions as in the case of the reduction of aerosol and Chlorofluorocarbon use on the discovery of the ozone hole in 1985. This led to the Montreal Protocol (1989) banning these substances.

In addition to ecological value, social values and perceptions play an important part in the function of an ecosystem (de Groot et al. 2012).

Assessing the Value of Research

Research in Antarctica comes with a host of logistical challenges, so determining what research to support is essential. This is where research assessment comes in. Research is assessed for various different reasons, such as comparisons, evaluations, effectiveness, investment success, ranking, and decision-making. In this context, the value of research relates to whether the research is important and beneficial. Research assessment can be global, or compared between countries, organizations, and individuals. It gives a good idea of who is doing the work and where the work is being done, which is useful information in understanding the progression of science or a particular field.

Antarctic research is important because of the unique nature of the Antarctic environment and the critical role it plays in the Earth System. However, there is a need to quantify just how important, and what impact it has on the research community, wider community, and society in general (Sutherland *et al,* 2011). In this report, we have touched already on the different types of values that motivate individuals to conduct research in Antarctica. This section will discuss the various different ways that research output can be assessed in order to identify the value of the research.

Research is assessed using a variety of different metrics:

- Bibliometrics is the study of scholarly publications, the traditional output of a research project, and measures the impact of this particular piece of research.
- Citation analysis investigates how often scholars are cited in different publications and is an indication of relevance and research impact.
- Impact factor is the impact of a scientific journal, as some journals have a higher impact factor than other journals. Publishing a paper in a journal with a higher impact factor will increase the chance of being cited, and research having a greater impact.
- Scientometrics is the study of science, technology, and innovation. This is the analysis of the science literature, but there are other indicators of research success.
- Altmetrics, or 'alternative metrics' looks at alternative measures for determining the impact or success of research, and is a burgeoning field in research assessment (Van Noorden, 2010).

Figure 2 shows the development of research from pure and applied research through to benefits to society. This is a useful way of showing different approaches to assessing research at different points along the timeline, such as citation analysis of publications in the research phase, through to citations in policy reports in the dissemination and development phase.

The authors note that there are challenges in this simplistic model. It can be difficult to attribute a societal impact to a particular piece of research, and there may be a substantial time lag between research and application. Research outcomes are not always utilized, and politics may come into play as in the case of climate change research, or from a combination of commercial factors. Finally, there is the complex nature of impact, with some impacts difficult to define. In the UK, a 'pathways to impact' qualitative assessment is used on knowledge transfer activities that are an attempt of the researcher to ensure the results of their research is applied. This promotes engagement between scientists and the people who will benefit from the research, and reduces the likelihood of the research not living up to its potential impact.

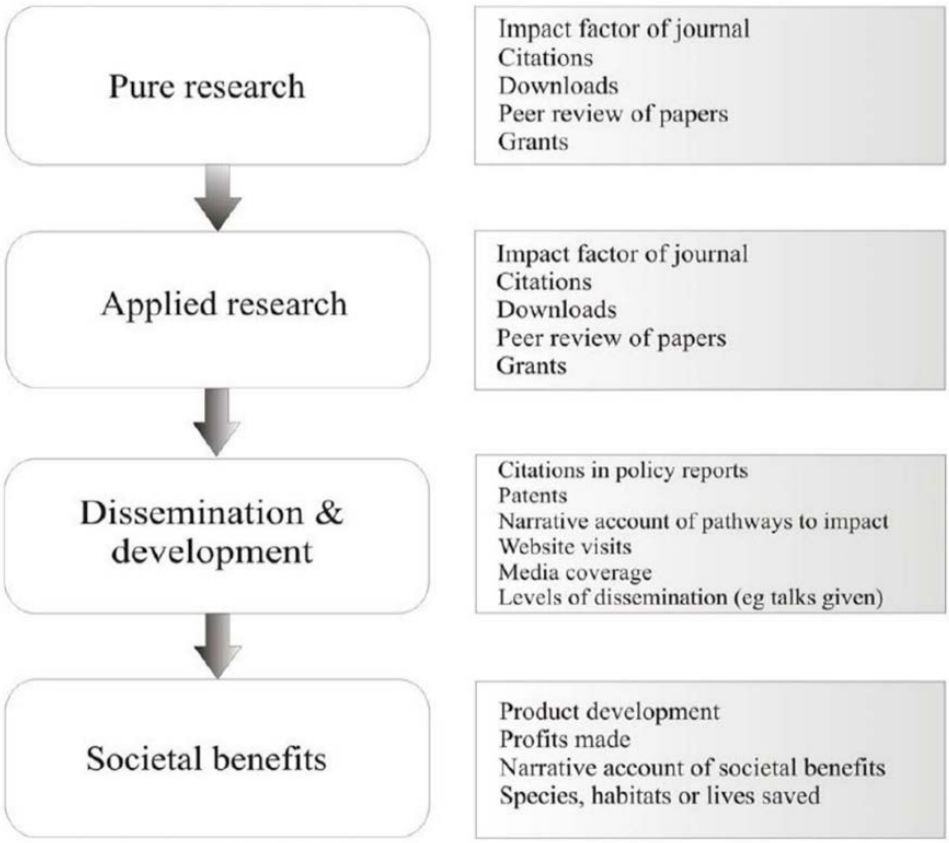

Figure 2. Main components of the progression of science into practice and societal benefits (left), with some existing measures of impact and quality (right). Source: Sutherland *et al.* (2011).

Antarctic research assessment

In a study by Dudeney and Walton (2012), Antarctic research is examined specifically in the context of the Antarctic Treaty. The authors note that Antarctica is one of the few areas where science output in the form of publications can be linked to policy and politics in a straightforward fashion. This further emphasizes the significance of Antarctic research and the need to undertake reliable research assessment. Consultative Parties (CP's) to the Antarctic Treaty assume a management role, but parties must first demonstrate the contribution of their scientific research. In the study, this is indicated by the submission of Working Papers, which require action when submitted at the Antarctic Treaty Consultative Meetings, and Information Papers, which are only discussed when requested. A greater contribution of Working Papers demonstrates greater engagement in the Antarctic Treaty, which is shown in descending total number for different parties in figure 3.

Performance of the CP's is compared with the production of publications produced, with the finding that greater engagement in the Antarctic Treaty System (ATS) is correlated with a greater science output. Also noted in the study is the observation that the ATS has no formal mechanisms for reviewing research performance of a CP once this status has been met. To combat this, the authors suggest that parties have regular peer reviews of their research programs, with the results made available to other parties.

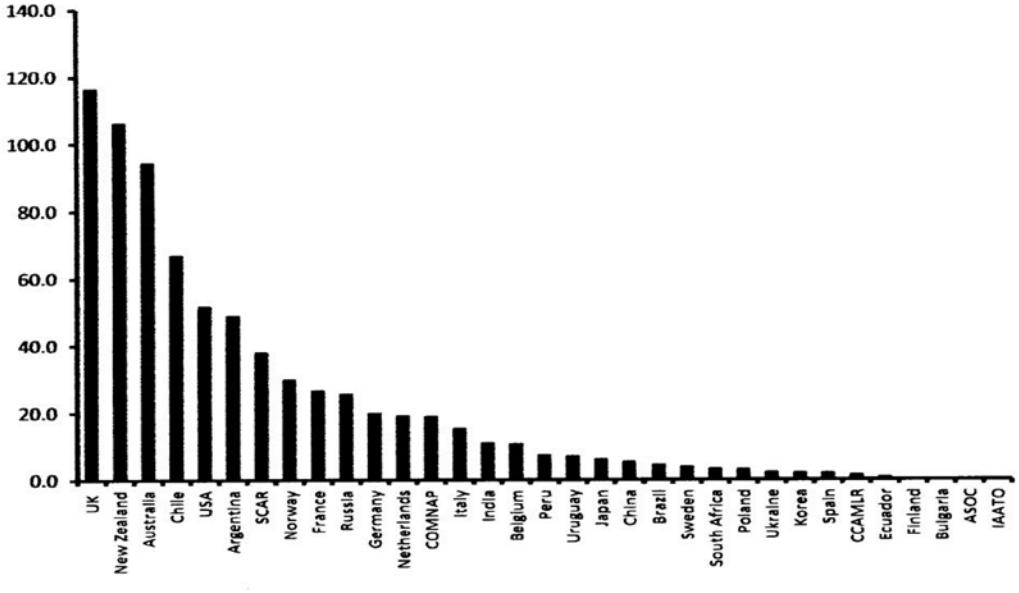

Figure 3. Total sum of Working Papers produced by each of the Parties to the Antarctic Treaty for the period 1992-2010, ordered by descending total number from the left-hand side of the plot. Source: Dudeney & Watson (2012).

Scientometrics and network analysis techniques were used in a study by Dastidar (2007) to analyse journal publications on Antarctic science over a period of 25 years, from 1980 to 2004. The purpose of this study was to identify the nations and institutions that have the greatest output of journal publications on Antarctic science using the Thomson Scientific's Citation Index database. Results showed that the overall number of journal publications relating to Antarctic science were increasing, as well as publications with authors from different countries. This is illustrated in figure 4.

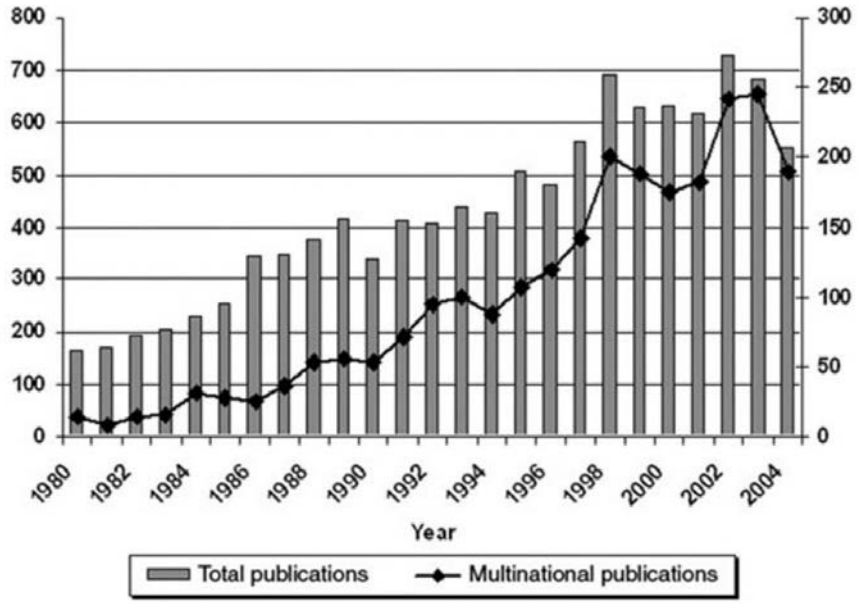

Figure 4. Overall number of journal publications with "antarc*" in the title, and the number of these publications co-authored by writers from different countries. Source: Dastidar (2007).

An important finding of this study is that science productivity is investment dependent, as countries that were the most productive in terms of science output had higher inputs to research and development. In terms of research impact, *Nature* is the most highly-cited journal in Antarctic science with 4,634 citations over the same time frame from 1980 to 2004 (Dastidar & Ramachandran 2008). The journal *Science* is the second most highly-cited with 3,351 citations, followed by *Polar Biology* with 2,722 citations. This contrasts with the most productive journals in Antarctic science, with *Polar Biology* publishing 987 articles in the 25-year study period. *Nature* published 206 articles and was the 7th most productive journal, and *Science* published 113 articles and was the 14th most productive journal. An understanding of journal productivity and citation analysis of different journals can help illustrate trends in Antarctic science research.

One example of the benefit of Antarctic research is discussed in a study by Persson & Dastidar (2013) by analysing the development of Antarctic ozone hole research, significant papers, and contributing players. A data set of 362 articles were found and citation links and a citation network map were formed. This research lead directly to the drafting of the Montreal Protocol, which came into effect in 1989, and lead to the production of ozone depleting substances being phased out. Figure 5 shows the growth of Antarctic ozone hole research, with the red arrow indicating the Montreal Protocol and the largest spike in scientific articles published.

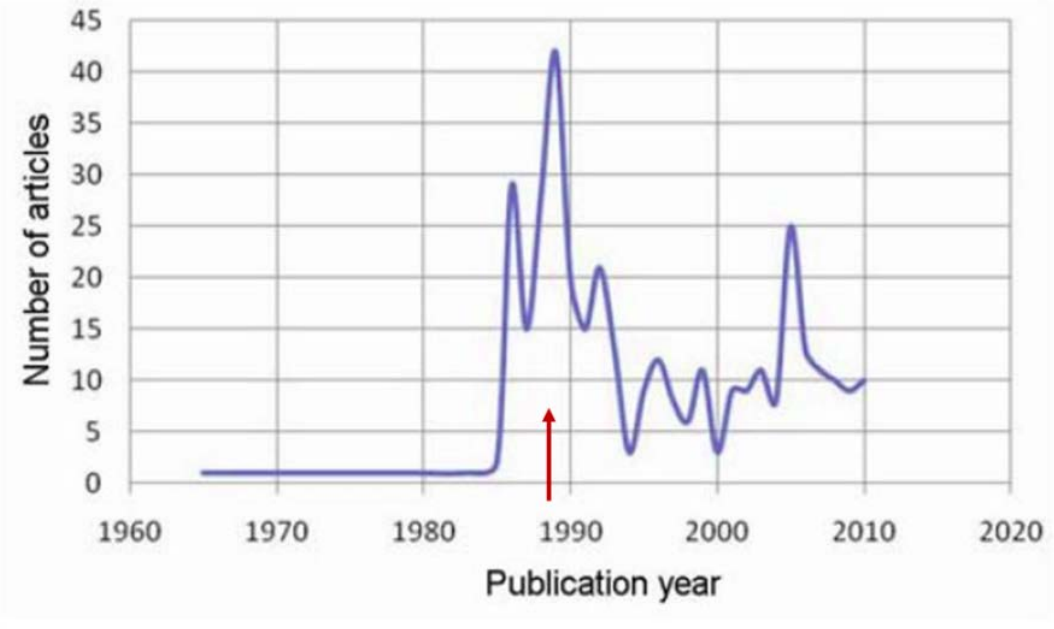

Figure 5. Growth of scientific research in Antarctic ozone hole research. Source: Persson & Dastidar (2013).

The authors were able to rank the top most productive countries in ozone research in Antarctica, with the USA producing 190 articles followed by the UK with 48 articles. Two researchers from the USA and one from Germany were awarded the Nobel Prize in Chemistry for the contribution of their research. Citation analysis was able to track the development of this field, which ultimately lead to direct action and an international environmental movement.

Considerations

Although traditional metrics for research assessment have proven merit in understanding the landscape of Antarctic research, there are known flaws to keep in mind. Citations are slow to appear, and a standard in bibliometric analysis is to allow 3 years for a reliable measurement of impact (Bornmann & Leydesdorff 2014). Also, in some cases, research impact may not become apparent until years after publication. Citation analysis does not distinguish between citations due to discredited science and verified science and favours older researchers (Lane 2010). In addition, bibliometric and other citation analyses can only be applied when there are appropriate databases available, where some disciplines may be more represented than others (Bornmann & Leydesdorff 2014).

There are a wide range of research activities that existing metrics do not capture. Metrics are important for decision making and understanding the dynamics of Antarctic research, and Lane (2010) points out that that narrow measurements of scientific achievement may lead to narrow or biased science. Research products are no longer limited to traditional publications, but can be as varied as databases, patents, YouTube videos, products developed, software, and websites (Bornmann & Leydesdorff 2014, Piwowar 2013). It is now possible to measure research engagement in new ways, using recent data. Applying altmetrics to Antarctic research may be beneficial in understanding the wider impact of research, and in different sectors of society through download statistics and social media analysis (Bornmann & Leydesdorff 2014). Although a perceived disadvantage of download statistics is that there is no differentiation between public views and views by scientists, the advantage is that it expands the range scientific impact to not just traditional citations (Van Noorden 2010).

Finally, in order for a wider range of research assessment to be effective, data infrastructure to support alternative metrics must be developed that is both open and consistent, to allow comparison between different fields (Lane 2010). Existing mechanisms of evaluation are often not compatible with alternative products (Piwowar 2013). As well, the analysis and interpretation of data necessitates the involvement of social scientists, not just those traditionally involved in capturing the data (Lane 2010).

Research assessment is undertaken in order to understand the value of research in a way that allows it to be compared and analysed. Although existing metrics have known flaws to consider, assessment of Antarctic research has provided valuable information on trends in research, productivity in different researchers, organizations, and countries, and influence within the ATS. New measures of assessing research can help broaden the scope of impact, and lead to greater recognition of the value of the overall intellectual contribution of Antarctic research.

The Values of Antarctic Research Stakeholders

There are a number of stakeholders who have a part to play in Antarctic research. For the purpose of this report, Antarctic stakeholders are defined as being those actors or organizations who have an influence on Antarctic research and therefore have underlying values which are assigned to the research, as well as to Antarctica as a place.

Antarctic stakeholders can be generally separated into four groups in order to try to encompass all actors, all with differing values. These groups are the researchers themselves, governance stakeholders, corporate stakeholders and the wider public. A flowchart of these stakeholders can be found in Figure 6. The researcher stakeholders include not only individual researchers, but also the institutes who conduct Antarctic research. Within research stakeholders, we must also consider the large range of disciplines of Antarctic research, across both the sciences and humanities. The governance stakeholder group includes the policy makers and those organizations which influence political decisions in regards to Antarctic research. Governance stakeholders includes the international bodies who influence Antarctic research, as well as domestic governments. The corporate stakeholders include all businesses who have an interest in Antarctic research, including fishery companies, tourism operators and any private company which may sponsor Antarctic research. Lastly, the wider public includes individuals within the community as well as NGO's who hold values regarding Antarctica.

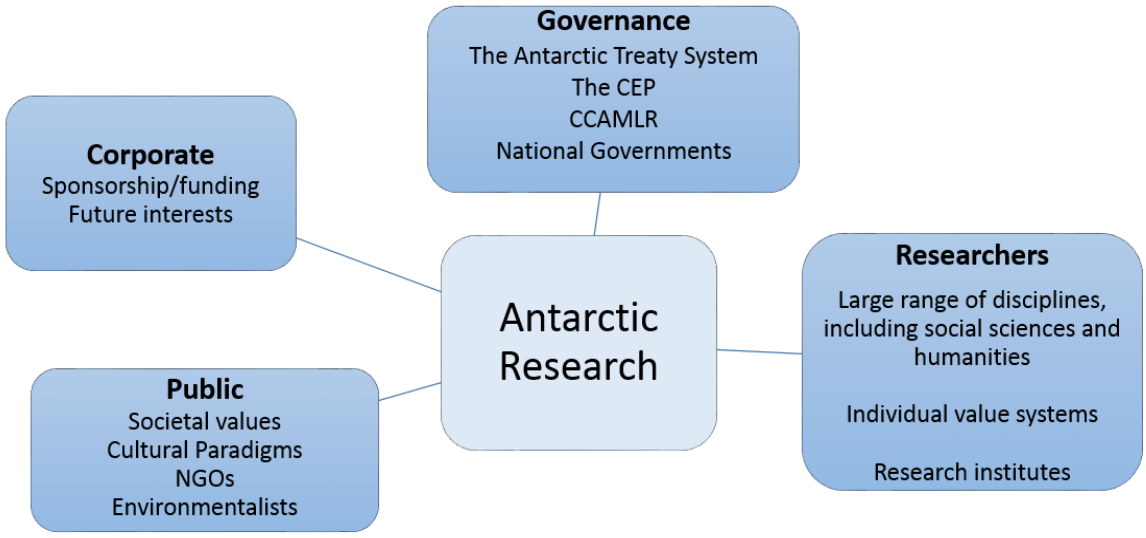

Figure 6. The four key groups of Antarctic research stakeholders

Researcher Stakeholders

Antarctic researchers, as well as the institutes which they come under, are integral stakeholders in Antarctic research as a whole. Both the individual and collective values of these groups may have an effect on the types of Antarctic research which is conducted, and the outputs of this research (SCAR Social Sciences Action Group, 2013). Antarctic researchers may operate under a variety of institutes and organizations, all with potentially differing values. These institutes include government funded multi-disciplinary institutes, universities (both private and public), as well as scientific institutes. All of these institutes have an important part to play in Antarctic research, especially through the funding of research, the groundwork of conducting research and the publication of the outcomes (Kennicutt, et al., 2014). Research institutes may have value systems built into their foundations and into their science goals. These values may then define the direction of Antarctic research and the outcomes associated with this research. Funding further complicates this issue (Kennicutt, et al., 2014). Often scientific institutes will have limited funding to assign to Antarctic research projects, and therefore values may come into play when choosing what research goes ahead.

In terms of the individual researchers, the basic human values of researchers may influence the type of research they are interested in focussing on and which they may then continue to focus on for the duration of their research career. For example, a certain researcher's ideas about intrinsic and aesthetic value, may lead them to environmentalism, which may influence the type of research they choose to conduct, and the methods which they choose to use (SCAR Social Sciences Action Group, 2013). Having these values not only defines the specific research that is being undertaken, but also leads the researcher to focus on one discipline over others. This may create more popular disciplines, depending on the researcher's individual values (Kennicutt, et al., 2014).

In the history of Antarctic research, the focus of research topics has changed significantly. This change in research areas may show a different emphasis as the scientific institutes' values shift. In the early 1800's, the focus of Antarctic research and particularly Southern Ocean research, was on navigation and the resources which could be harvested from the Southern Ocean (Kennicutt, et al., 2014). This was largely because of a need for accurate mapping and navigation for trade routes. From 1910 until the Geophysical year of 1957/58, which has been coined the Heroic Era of Antarctic exploration, a focus was put on geology and meteorology (Kennicutt, et al., 2014). Antarctic research has increased its breadth in the past few decades and now covers a large range of disciplines, both across science and humanities areas. However, there are still charismatic research areas, namely climate change (Kennicutt, et al., 2014). These changes in scientific focus may reflect not only the needs of the time, but also the values of the researchers and their organisations.

Governance Stakeholders

The governance stakeholders involved in Antarctic research include both international and domestic bodies, as well as other organisations which may externally influence political decisions, for example SCAR and COMNAP (SCAR, 2015). The values demonstrated by the international governance stakeholders are shown through the Antarctic Treaty system, in particular the Protocol on Environmental Protection to the Antarctic Treaty (the Madrid Protocol) of 1991 and the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR) of 1982 (CCAMLR, 2013).

However, these values have been difficult to define and may be interpreted in different ways by Parties at a domestic level (SCAR Social Sciences Action Group, 2013). Within this, there may also be cultural paradigms at play which effect the values of the Parties and how they choose to enact these values (O'Riordan, 2014).

In the preamble of the Antarctic Treaty (1959), it is stipulated that Antarctica shall be used exclusively for peaceful purposes and stipulates the importance of scientific research in Antarctica (Preamble, Antarctic Treaty, 1959). This in itself shows a prioritisation of scientific and ambivalent values by the 12 initial signatory States. However, the Antarctic treaty does not mention these as specific values and it was not until the introduction of the Madrid Protocol in 1991 that *values* were specifically mentioned in relation to Antarctic governance. In Article 3 of the Madrid Protocol, the aspects of wilderness and intrinsic values of Antarctica are mentioned, in the context of them needing to be preserved (Article 3, Madrid Protocol, 1991). However, the Madrid Protocol does not go so far as to define these values.

Since 1959 when the Antarctic Treaty was signed, the number of signatory states has increased from the 12 original States, to 52 signatory Parties and 29 Consultative Parties in 2015 (Antarctic Treaty Secretariat, 2015). Consultative Parties are those Parties which have an active vote at the annual Antarctic Treaty Consultative Meetings (ATCM). Because of this large increase in Parties, this has increased the number of stakeholders in Antarctic research and therefore the range of values which are involved (SCAR Social Sciences Action Group, 2013). With so many signatory States and Consultative Parties, cultural paradigms may come into play. A cultural paradigm is the idea that a group of people will have the same or similar assumptions and perceptions about the world, due to where they grew up and the culture they were raised in (O'Riordan, 2014). Such differences in values at a fundamental level may play out through an international governance system, such as the Antarctic Treaty System.

A recent example of cultural paradigms at play is shown through the proposals of Marine Protected Areas (MPAs) through the CCAMLR system and the rejection of them by Russia and China. Different MPAs have been proposed for the Ross Sea and East Antarctica regions by New Zealand, the United States, France and Australia each year since 2011, yet have been turned down by a small number of states, including Russia and China (AOA, 2015). At the October 2015 CCAMLR Commission meetings, China agreed to the amended Ross Sea MPA proposed by the US and NZ, leaving only Russia to object (CCAMLR-XXXIV Meeting Report, 2015). Because CCAMLR works on a consensus basis, one objection to the MPA means that it will not be designated. However, this objection from Russia comes down to cultural paradigms, as Russia as a nation fundamentally rejects the idea of MPAs, instead opting for resource use, economic outputs and ultimately power (AOA, 2015). In this case, Russia's cultural paradigms may put other values in jeopardy, especially the intrinsic value of Antarctic marine living resources. Cultural paradigms are a base and fundamental part of a State's views on certain issues and with such a large number of Antarctic governance stakeholders, are something that must be considered (SCAR Social Sciences Action Group, 2013).

At a domestic level, a difference in values can mean the difference between interpreting the Madrid Protocol as an instrument used for environmental protection, to viewing Antarctica as a treasure-trove of resources (Brady, 2013). There have been a number of Parties who have expressed an

interest in the commercial uses of Antarctica, especially in terms of resources, which shows an emphasis on economic values rather than environmental values (Brady, 2013). These political decisions are influenced by both individual representatives and the collective view. There may be times were individual representatives have a large amount of influence due to having to make specific decisions in political discourse (SCAR Social Sciences Action Group, 2013). However, at the same time, there may be overarching collective values, for example of their government, that they are trying to represent.

Corporate Stakeholders

The corporate stakeholders of Antarctic research include those companies or organizations which have commercial interests in either the Antarctic region itself, or the research coming from Antarctica. This includes fishery companies, tourism operators, private contractors for National Antarctic Programmes and companies who sponsor research. These stakeholders may have a direct output from Antarctica, through a product, or otherwise an indirect output through research outcomes. The corporate stakeholders may have varied values and may be focussed more on the company's goals, rather than the values enshrined in the Madrid Protocol which may bring up a conflict of values.

Many companies have an interest in Antarctica because of economic value and output, which may be in opposition to environmental values. Fishery companies are a prime example of this. Although quotas are set by CCAMLR, arguably the economic focus of these companies may not be compatible with the intrinsic, wilderness values of Antarctica. However, scientific values may still be valued by these companies, as CCAMLR quotas are guided by scientific advice and often fishing vessels may assist in scientific research, through the Ships of Opportunity system and other initiatives (CCAMLR, 2013).

The intrinsic and wilderness values of Antarctica can also be at the forefront of corporate stakeholders' business models. Tourism operators within Antarctica rely on these values in order to attract customers (SCAR Social Sciences Action Group, 2013). Antarctica as a tourist destination is advertised as being a pristine wilderness environment and this is where the appeal lies. Therefore, the International Association of Antarctic Tourism Operators (IAATO), which is the industry body of tourist operators in Antarctica, must have these values as a part of their organization. This is shown throughout their policies and procedures, as they put the intrinsic and wilderness values of the Antarctic environment at the forefront of their operations (IAATO, 2016).

Corporate stakeholders of Antarctic research are a broad group of stakeholders from different commercial sectors. They therefore have a large variance in values. Some of these values may be quite different to the values stipulated in the Madrid Protocol, while others, such as the tourism operators, may align with those values quite closely.

The Wider Public

The wider public and members of the community are stakeholders in Antarctic research in that they may be the audience for research outcomes, as well as being integral to having opinions about Antarctica which may then influence political actors. The values which the wider public associates with Antarctica may be due to personal values, but also relates to their awareness and knowledge of the place (SCAR Social Sciences Action Group, 2013).

Antarctica has had a relatively short human history, as well as having no permanent human inhabitation. Due to this, in the past Antarctica as a place has had a low level of awareness by the general public (Shah, 2015). This may change the values that the public associates with Antarctica. In the past, particularly during the Heroic Era (1910-1957), Antarctica was largely seen by the public as a place of exploration, but also as an isolated and desolate place (Shah, 2015). Antarctica has also been subjected to values of nationalism by the public, through territorial claims from a number of countries (Kennicutt, et al., 2014). More recently, the awareness of Antarctica has increased, especially with the popularization of global issues such as climate change (Shah, 2015). This heightened awareness may result in the wider public becoming more interested in Antarctic research as a whole, as well as an increase in the appreciation of the intrinsic and wilderness values of the place. It may also mean that new values are imposed on Antarctica through further engagement with the place by a broader range of people.

A heightened awareness of Antarctica and increased participation of the wider public as stakeholders in Antarctic research may result in changes of the focus of Antarctic research, through public pressure, or otherwise changes in Antarctic governance, particularly through the use of Non-Governmental Organisations (NGOs). There are many NGOs who act as stakeholders to Antarctic research by conducting their own research, increasing the awareness of the wider public and by lobbying governmental stakeholders to make certain decisions. The Antarctic and Southern Ocean Coalition (ASOC) is a large Antarctic NGO which focusses on the preservation of the Antarctic environment, especially through the promotion of MPAs (ASOC, 2014). There are also many other NGOs who have focuses on specific Antarctic environments (either marine or terrestrial) or on global issues such as climate change (Princen et al., 1994). These NGOs exhibit specific value sets, particularly of those which are embodied within the Madrid Protocol and ones of environmentalism.

The Political Worth and Economic Value of Antarctic Research

The United Kingdom claimed the Ross Dependency in 1841. It transferred this claim to New Zealand in 1923. Other nations have also laid claim to parts of the continent. While the 1959 Antarctic Treaty put all of these claims on hold and forbade the lodging of new claims, the existing ones have not been relinquished. All of the claimant states seek to preserve their claims, within the parameters of the Antarctic Treaty System (ATS) and its protocols. Other countries have joined the ATS over the years, especially since the possibility of mineral resource extraction was raised during the 1980s. Many have an interest in securing economically viable resources there, if a mining regime is ever agreed. They and others are also interested in the Southern Ocean's fishing and other resources.

Accordingly, the Government's first goal, as reflected in Antarctica NZ's Statement of Intent, is for New Zealand to maintain a continuous and effective presence in the Ross Dependency, through Scott Base and the research activities that Antarctica NZ supports. The specific outcome sought is to secure New Zealand's interests in Antarctica through an increasingly effective ATS (Antarctica NZ Statement of Intent 2013-2016, p11). For a small nation such as New Zealand, working within an effective rules-based system is the best way of influencing others. Science and collaboration are commonly accepted to be the currency of diplomacy in Antarctica (Brady et al, 2012).

The other ways that New Zealand seeks to have influence is through the quality of scientific research that it undertakes, often in collaboration with other countries, and its strong commitment to Antarctic environmental protection. Specifically, the second goal in Antarctica NZ's 2013-16 SoI is:

2. The Antarctic environment is protected more effectively, in accordance with the Madrid Protocol and New Zealand's Antarctica (Environmental Protection) Act 1994.

Ways of delivering better environmental protection discussed in the SoI (ibid, pp 15-20) include:

- A 'no harm' approach to accidents and environmental incidents;
- Encouraging a culture of sustainability;
- Completing Environmental Impact Assessments in accordance with the Protocol;
- Supporting marine protection, vessel safety and search and rescue activities in the Ross Sea;
- Ensuring that New Zealand's contributions to the joint US/NZ logistical pool are valued; and
- Conserving the historic huts and other heritage sites in the Ross Dependency.

The third SoI goal (ibid, pp 20-23) is

3. The quality and relevance of New Zealand's Antarctic and Southern Ocean science is improved.

This is the focus of much of the remainder of this part of the syndicate's report.

The fourth key SoI focus (ibid, pp 25-27) is:

4. New Zealanders have greater awareness and knowledge of the importance of Antarctica.

This includes helping people understand Antarctica and the value of New Zealand's involvement there better, through publicising:

- The significance of the science done to understanding and mitigating human-influenced global change and in protecting the land, ice shelf and marine environments;
- Celebrating New Zealand's involvement in Antarctica since the heroic age;
- Understanding the economic impacts to all of New Zealand of having Christchurch as a key gateway city (discussed in more detail in a later section);
- Supporting appropriate media coverage and public Antarctic-related festivals;
- Undertaking public awareness and support surveys and addressing identified weaknesses;
- Antarctica-focussed websites; and
- Supporting young scientists and appropriate arts-related activities in Antarctica.

The Quantification of Economic Value

In figure 7 below, the vertical axis shows increasing certainty in the results from a research proposal. The horizontal axis shows increasing ease in being able to quantify the returns (i.e. fewer returns that are difficult to measure in cash terms). The upper right hand corner reflects the rare case in which the research results are fully predictable and their value is measurable. In Antarctic research, an example might be Southern Ocean toothfish number assessments. The bottom left hand corner reflects the situation where no real analysis is possible, so the decision on whether or not to support a project relies on judgement – 'educated guesswork'.

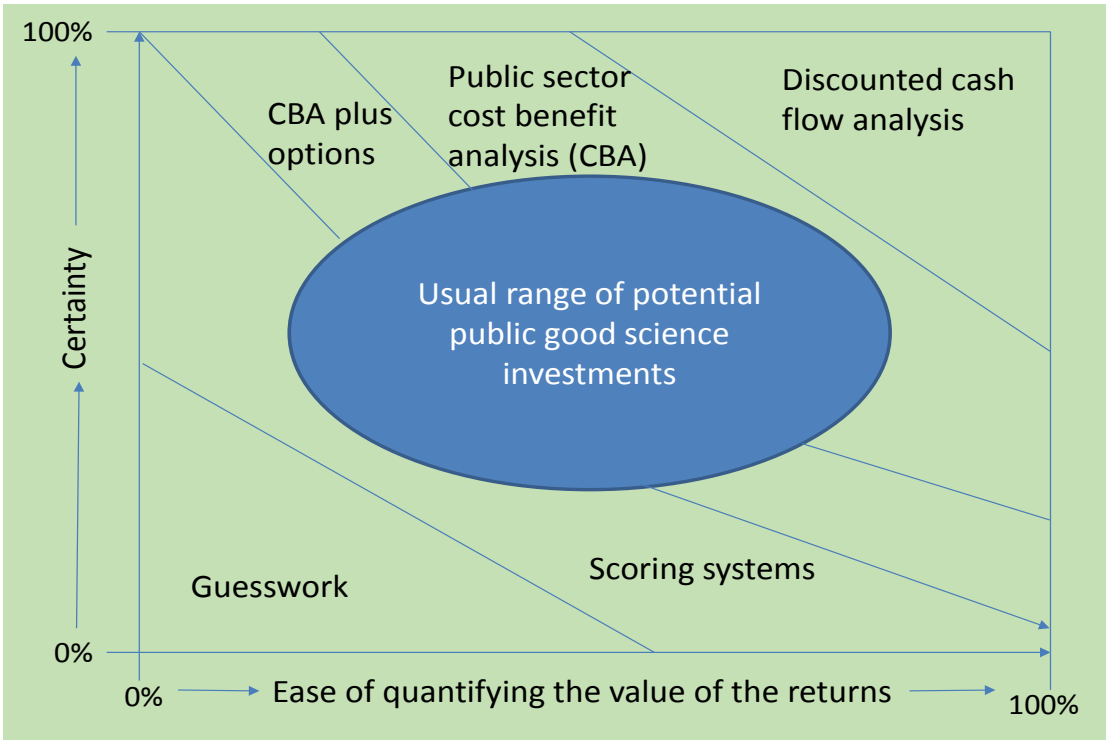

Figure 7. Methods for quantifying the potential value of research before it is undertaken.

Moving from the top right hand corner back to the left and down, we progress from the domain where profit-orientated net present value analysis works well, through public sector cost-benefit

analysis (CBA) and options valuation to a large area where scoring systems are the primary analytical tool. The criteria most commonly used in scoring systems are discussed in the next section.

Some costs and potential returns may be very difficult to quantify reliably. The uncertainties involved may be considerable. Nevertheless, the effort is worth making:

'Presently, there is no widely accepted way for the Federal Government to make priority decisions about the allocation of resources in and across scientific disciplines…Thoughtful efforts have helped lay the foundation for future efforts …The Board recognises that this task is difficult and controversial and that many scientists consider it both undesirable and undoable…However, it is inescapable that allocations will be made on the basis of whatever understanding and methodology are available to inform the process at the time' (US National Science Foundation Board, 1998 Strategic Plan, p 9.)

Overlaid in Diagram 9 is the range within which typical public good research proposals usually fall. Where quantitative approaches can be used in a cost-effective manner, they make the process more accurate and less subjective. Proposals can be ranked. This is the core of the methodology that is often applied in contestable funding rounds, as there is never enough money available to support all of the proposals submitted.

National cost-benefit analysis usually has to consider trade-offs among conflicting public sector objectives, which makes the task harder. It is sometimes feasible for environmental research decisions, where the benefits are not income earned but instead are savings made by averting or mitigating environmental costs. Some such work has been done (e.g. Stern, 2006). There is an emerging consensus that climate change would increase income inequalities between and within countries. A 2 °C increase in global mean temperature would result in net negative market sector impacts in many developing countries, with some Pacific island nations being especially vulnerable even to small sea level rises, and net positive market sector impacts in many developed countries. Bigger temperature changes or sea level rises would be highly negative nearly everywhere.

Some writers argue that cost benefit analysis is not the best approach. For example, Mitchell (2009) asserts that the use of scenarios and 'adaptive management' is better for handling uncertainty and in managing complex systems than traditional techniques, such as CBA. There may be many factors that interact in ways that are hard to separate in dynamic systems. The use of complex simulations and robust planning that adapts as new data are found may improve the outcomes, especially since taking some actions early may be better than waiting to apply an optimal approach later.

There is another reason to be dubious about the value of CBA for environmental research. In CBA, the value of future benefits is discounted to the present day. The discounting principle seems questionable for very long term decisions, which are the norm in environmental economics. Long-term sustainability is one critical issue. Ethical issues are widely debated, such as the trade-off between the use of a depleting resource and the needs of people yet unborn. Some also argue that the integrity of nature has an inherent value, rather than just as a resource for humans. Value judgements such as this underpin the ATS's Madrid Protocol.

Antarctic Science Criteria

Public good research focuses mainly on observable phenomena and facts that increase the stock of knowledge or the understanding of physical, biological or social environments. Most Antarctic research falls into this category. The results become more valuable when they can be used. The criteria that are most often applied globally to allocate resources for public good research are:

- Science merit or excellence (often assessed with reference to the collaborations proposed, the ability of the research team to deliver what it is proposing to do, its track record, and peer review by other experts in the field of study);
- The relevance, probable potential usefulness or contribution to agreed outcomes or values of the work proposed; and
- The cost effectiveness of the work, since the logistical costs of Antarctic-based research are so high.

In New Zealand, which has relatively few researchers in most fields, finding peer reviewers who have no conflicts of interest can be difficult. NZARI, MBIE and the Royal Society (for the Marsden Fund) all use variations on the above approach. The goal is not so much to identify the very best and to eliminate just the worst proposals, but to separate the mass of proposals in the middle that might be worthwhile supporting.

As has already been discussed, the science merit of work previously done by the proposers can often be assessed through bibliometric and citation analysis.

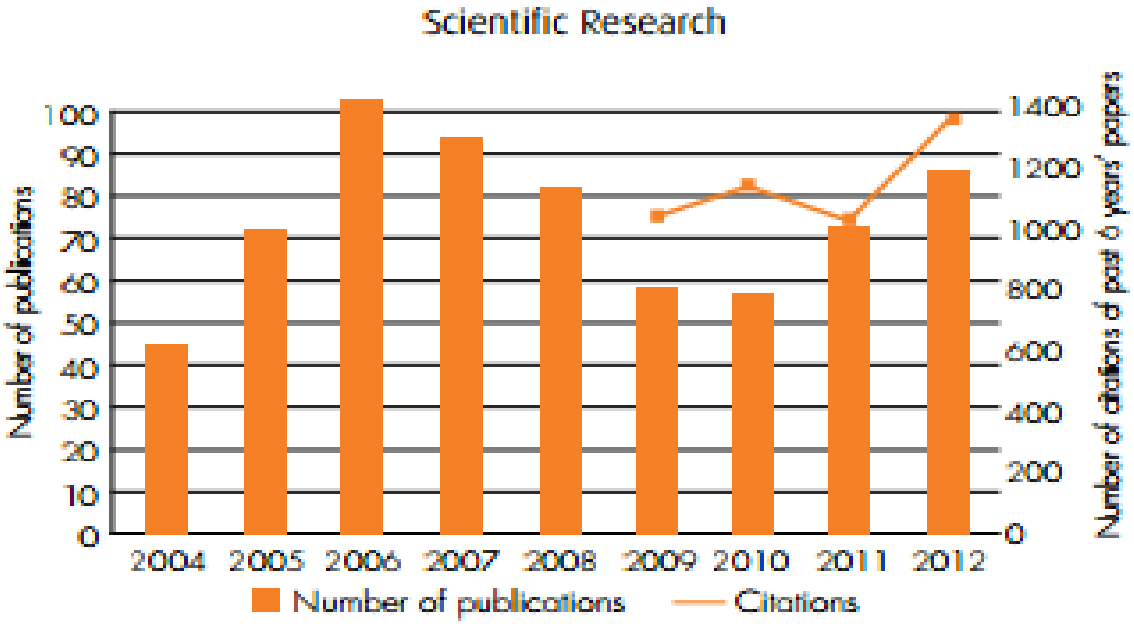

Figure 8. The number of peer reviewed papers published between 20004 – 2012 on scientific research that Antarctica NZ supported, and the citations of these papers since 2009 (Antarctica NZ's 2013-2016 Statement of Intent, p 22).

Figure 8 shows that:

- An average of about 75 Antarctic research papers p.a. were published from 2004 - 2012.
- The number of citations is on an increasing trend. The SoI states (p 22): 'The increase in citations of the previous 6 years' papers gives an indication that the quality of the science output has continued to increase. This is also clear from the increasing number of papers we are seeing in high-profile, high impact factor journals. This gives us confidence that we are supporting high-quality research.'

ANZARI's Antarctic and Southern Ocean Science Directions, 2010-2020

The New Zealand Government endorsed an Antarctic science strategy for 2010-2020 in 2011, after a period of public consultation during 2010. This focuses on the types of Antarctic research that it sees as being most valuable. It requires all of New Zealand's public sector science funding sources to align with the framework, with a partial exemption for the 'blue-skies' Marsden Fund. Since then, 'The Deep South' has also been chosen as one of the eleven National Science Challenges.

The ANZARI strategy is a good example of setting directions and values in a way that enables the outputs and outcomes that are achieved to be measured.

It covers three broad science areas:

1. Climate, cryosphere, atmosphere and lithosphere;
2. Inland and coastal ecosystems; and
3. Marine systems,

all within a unifying and overarching theme of global change, to help understand and manage human impacts in Antarctica.

For each outcome:

- 3-5 research goals are defined;
- New Zealand's potential contribution to the global effort is explained;
- 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.

Interdisciplinary and multidisciplinary efforts are encouraged. All proposals must demonstrate high scientific standards and credibility. The dissemination of findings to a wide audience, at home and abroad, is also sought. The strategy will be updated periodically, as knowledge and priorities evolve.

Post-Facto Evaluations

It can be even harder to evaluate what was achieved after the work has been done than in deciding what proposals to fund. Surprisingly few detailed evaluations of the results of public good research have been undertaken in New Zealand.

Other factors include:

- Some outputs may be unexpected. This is often a good thing. Many Nobel prizes have come from investigating surprise research results.
- The lags before benefits are realised can be enormous. For example, complex numbers were just an interesting C19th mathematical side-line until it was realised after World War II that they could explain the workings of electrical circuits.

In terms of global climate change, understanding the key physical processes of what has happened in the past in detail will enable progressively more accurate models of what is likely to occur over the next few centuries to be developed. This should help reinforce the urgency of policy change, global remedial actions and the development of new technologies that do not rely on fossil fuels.

Antarctica as a Domestic Economic Sector

Antarctic research, logistics, tourism and related activities have created thousands of jobs in New Zealand and have generated income in Canterbury and elsewhere across a broad range of business sectors, as shown in the following table:

Aspect	Canterbury	New Zealand	FTE jobs
National A Programmes	$38.7m	$46.5m	1681
Tourism	$31.8m	$29.0m	1422
Fishing	$17.7m	$71.0m	1874
Research	$4.9m	$9.8m	281
Heritage	$4.1m	$5.5m	161
Totals	$102.9m	$161.7m	5420

Saunders et al, AERU, 2013

Table 2. The Economic Impacts in New Zealand of Its Antarctica-Related Activities

- Ultimately, much of what happens in Antarctica is due to the research done there and the costs of supporting it. All the universities and most of the CRIs have some involvement.
- Christchurch is one of five global Antarctic gateway cities. The direct annual income from Antarctica-related activities for Canterbury in 2011/12 was $103m, and for New Zealand overall $162m. Normal economic multipliers more than double these numbers.
- The USA, New Zealand, Italy and Korea all base at least part of their Antarctic logistics operations in Christchurch.
- The fishing sector caught 972 t of toothfish, worth $71m, in the Ross Sea in 2011/12.
- Tourism includes visitors to the Antarctic attractions in Christchurch and Heritage Cruises.
- A total of 5,420 New Zealand FTEs are estimated by AERU to have been employed in 2011/12 in servicing all of these activities and in Antarctica itself.
- The benefits to Christchurch are promoted actively by the Government and Antarctica NZ. Emphasising these economic benefits is one of the purposes of the outreach programme.

Other Potential Economic Impacts of Global Antarctic Research

- Mineral resources - There are almost certainly a number of supergiant oilfields yet to be discovered in the world. Antarctica has in the past had similar vegetation to that which created large oil and coal deposits elsewhere. However, oil would almost certainly be very expensive to extract, and in any case the Madrid Protocol forbids it. Only low grade coal has been found. There are also almost certainly some significant metal ore deposits, but as with oil, these will probably lie under thick ice sheets.
- Marine resources – the Japanese remain interested in 'scientific' whaling. Other countries are eyeing the potential for taking more krill, toothfish and other marine species. One of New Zealand's key priorities is to see new marine Antarctic Protected Areas established, but not all ATS members share the same conservation values.
- Resolving the ozone hole problem - Returning the spring ozone concentration to pre-CFC levels seems achievable, though it will take decades.
- The growth of tourism – the Antarctic cruise industry seems highly likely to continue to expand. It will have environmental impacts and will present an ongoing search and rescue risk. On the other hand, these vessels may contribute usefully to the collection of useful climate and current data, through 'citizen science' activities.
- Weather forecasting - Antarctic weather data is useful for modelling near-term weather events, not just climate change. Antarctic oceanic currents and wind patterns affect the weather far away, including in New Zealand.
- Bioprospecting and new technologies – the Space Age led to Velcro and Teflon as unexpected by-products. Several potentially useful industrial and therapeutic Antarctic antifreeze and medical compounds have already been isolated. Some could have commercial value. However, research results that are potentially patentable may be kept secret, rather than being freely shared, as the ATS requires.

Successful Collaborations

Examples of successful collaborative research that New Zealand researchers have played significant roles in include:

- paleoclimate drilling initiatives (such as Andrill, in conjunction with the USA and others);
- Ross Sea biodiversity and fisheries studies;
- mapping and hydrographic work;
- Dry Valleys geological and biological studies;
- long-term climate studies into sea ice, the atmosphere and ocean circulation;
- ozone hole work; and
- a wide range of environmental programmes in the Ross Dependency.

New Zealand also participates in a number of long-term monitoring programmes, and over the years, it has played a key contributory role at the Scientific Committee in Antarctic Research, CCAMLR and other science forums. It also hosts the COMNAP (Council of Managers of National Antarctic Programs) logistics group. New Zealand has not tried to participate in everything, but

generally speaking, it has worked hard to be a good member of the global Antarctic community, and to use its limited resources well.

Conclusions

The intrinsic value of Antarctica as seen to be one of the last wilderness areas of the world, and the importance that this ecosystem has to the rest of the planet as a driver of sea currents and atmosphere gives Antarctica a high value to all peoples of the world. The values held by a country or individual may be common to many or may differ from others. Values are important to define and to consider, as they motivate the actions of those who hold the values, now and in the future. This includes different stakeholders, the treaty parties and the scientists involved in Antarctic research.

Although existing metrics have known flaws to consider, assessment of Antarctic research has provided valuable information on trends in research, productivity among different researchers, organizations, and countries, and influence within the ATS. New measures of assessing research can help broaden the scope of impact and lead to greater recognition of the value of the overall intellectual contribution of Antarctic research.

There is a large range of stakeholders who have an influence in Antarctic research. Each of these stakeholders has differing sets of values, which play out in an Antarctic context. The values which stakeholders hold influence governance decisions as well as defining the focus of Antarctic research. They are therefore important to consider. Because of the large number of stakeholders and the values at play, the whole system is dynamic. It may change in the future, perhaps further towards protection and environmentalism, or possibly towards a more commercial future for Antarctica.

Science and collaboration are the currency of diplomacy in Antarctica. They serve New Zealand's and many other governments' aims well. Especially for small nations, working within an effective rules-based system such as the ATS is the best way of influencing others.

The main economic value added of Antarctic science generally is likely to be through helping to minimise the impacts of climate and other human-induced global environmental changes. Marine resources and tourism are also significant but mining land-based minerals is unlikely while the ATS and its Protocols remain in force.

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