Providing useable knowledge for decision making on climate adaptation issues:

a case study exploring the interactions between CSIRO and Australian Government Departments

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The submitted thesis "*Providing useable knowledge for decision making on climate adaptation issues: a case study exploring the interactions between CSIRO and Australian Government Departments*" is my own work and all sources used in the thesis have been acknowledged.

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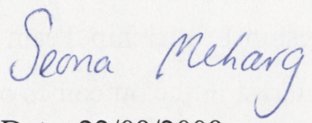

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Abstract

This sub-thesis sets out to explore how selected CSIRO researchers transfer useable knowledge to decision makers in Australian Government departments, the barriers they face in transferring that knowledge and opportunities for improving their communication practices.

This study compares CSIRO Climate Adaptation Flagship staff perceptions and practices with insights and techniques identified in the literature in order to explore what is the best way to provide useable science knowledge for decision making on complex issues such as adaptation to climate change. To do this, a comprehensive review of literature will be followed by a voluntary anonymous online survey and eight one on one interviews. Outcomes from the study suggest five opportunities for the CSIRO Climate Adaptation Flagship to improve their staff's ability to communicate useable knowledge to decision makers, including:

1. Clarify staff roles and expectations
2. Implement decision maker engagement plans
3. Train staff in communication skills, in particular how to engage effectively with decision makers
4. Reward staff for successful engagement with decision makers
5. Develop a network of CSIRO boundary individuals or knowledge brokers

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Abbreviations

CAF	Climate Adaptation Flagship
COAG	Council of Australian Governments
CSE	CSIRO Sustainable Ecosystems
CSIRO	Commonwealth Scientific and Industrial Research Organisation
IPPC	Intergovernmental Panel on Climate Change
NSW	New South Wales
R&D	Research and Development

1. Introduction

The Commonwealth Scientific and Industrial Research Organisation (CSIRO) is Australia's national science agency, constituted and operating under the provisions of the *Science and Industry Research Act 1949*. CSIRO's primary function is to carry out scientific research to benefit Australian industry and the community, and to contribute to the achievement of national objectives.

The mission of CSIRO Climate Adaptation Flagship (CAF) is to 'enable Australia to adapt more effectively to the impacts of climate change and variability and inform planning, regulation and investment decisions'. In order to 'enable Australia' CAF works with communities, industries, researchers, stakeholders and governments to learn and provide information for decision making. An important pathway for CAF to add value to Australian society is through working with Australian Government departments to inform policy decisions that take into account climate adaptation issues. This knowledge transfer is part of CSIRO's mandate and vital to achieving the Flagship's goal.

Background to the Study

Climate change is broadly considered one of the biggest challenges of our time, with the impacts of this change already being felt in society. Examples of these impacts include a rise in the frequency and intensity of extreme events, such as bushfires, drought and storms. As with all change, people need to adapt.

Adaptation is composed of the many actions and behaviours of individuals, groups and governments. These actions are motivated by numerous factors, including economic, risk, lifestyle and safety factors (Adger, Arnell and Tompkins, 2005). The Intergovernmental Panel on Climate Change (IPCC), the Stern and Garnaut reviews recommend that adaptation forms an essential part of climate policy. In fact the Stern Review went as far as to say that "adaptation is the only response available for the impacts that will occur over the next several decades before mitigation measures can have an effect" (Stern Review, p. xxi).

Societies, organisations and individuals have adjusted their behaviour in response to past climatic changes, and many are now contemplating adapting to altered future climatic conditions (Adger *et al*, 2005). In Australia, organisations such as CSIRO provide the Australian Government with information with which to make adaptation decisions (Science and Industry Research Act, 1949). Leaders have sought science advice since the time of Aristotle (384 BC – 322 BC), the science advisor to Alexander the Great. Institutions have also played their part throughout history with Isabella of Spain relying on the University of Salamanca for advice on scientific issues. In 1660 British researchers established the Royal Society, followed 60 years later by the French who developed the Académie des sciences to provide an independent source of science advice (Keough, 2002). In 1916 the Australian Government established the Advisory Council of Science and Industry as "the first step towards a national laboratory". The Council of Science and Industrial Research (CSIR), an earlier version of CSIRO, was created ten years later in response to a report on how Australian science should be organised.

Statement of the Problem

Science and technology today have an impact on most core government functions, underscoring the importance of science advice as a key input to policy formulation (Keough, 2000). Decision makers around the world are calling for the production and diffusion of more useful information for decision-making, particularly in areas such as climate change and the environment (McNie, 2007). Even though more information does not necessarily lead to answers for decision making. Nor does communicating research findings mean that what you have said has been heard or understood.

Researchers around the world are struggling with how best to provide information to users. In particular, science is increasingly called upon to provide information that can improve decision making in public affairs (Sarewitz and Pielke, 2007). This is certainly the case for CSIRO under the *Science and Industry Research Act 1949.*

Therefore, how best to communicate research findings to maximise knowledge transfer, and the type of information needed for decision making, are two questions that are vital for researchers and science organisations to consider.

Research Questions

This study will explore current understandings in the literature regarding what is useable knowledge for decision makers, and how this differs from expectations of knowledge transfer in the scientific community. As part of this, the literature review will explore the barriers to knowledge uptake, including the issues of uncertainty, knowledge and information gaps, and the inherent cultural differences between research organisations and governmental departments.

From the literature review a series of questions will be developed to investigate how CSIRO researchers currently communicate knowledge on climate adaptation issues to decision makers, what barriers they perceive to the transfer of knowledge, and how they think the process might be done better. Responses will be compared to similar case studies identified in the literature, in order to look at what might be the best way to provide useable science knowledge for decision making on complex issues such as adaptation to climate change. The following four questions will be addressed:

1. What does the literature hold as useable knowledge for the decision maker?
2. What are the perceived barriers to knowledge transfer from the researchers' perspective?
3. What do researchers' perceive to be the most effective and efficient pathways for communicating useable knowledge between CSIRO and Australian Government Departments?
4. How do these differ from pathways identified in the literature?

These questions continue to be explored in the literature highlighting that there is currently a lack of understanding on specific science/decision maker interfaces in Australia. In particular, this study will delve into what a selected group of CSIRO researchers perceive

to be the most effective and efficient pathways for communicating knowledge to Australian Government departments, their biggest stakeholder. CSIRO's current practices are compared to techniques identified in the literature, allowing for alternative pathways to be recommended.

Method

A descriptive case study approach is the preferred option for exploring the research questions, due to limited information about Australian researcher's perspectives on knowledge transfer in the literature.

In addition the literature suggested that case studies strive towards a holistic understanding of cultural systems in action, which is the aim of this research. Stake (1995) insists that all case studies must have boundaries; so this research focused on researchers from CSIRO's Climate Adaptation Flagship. After a comprehensive literature review and obtaining consent from CSIRO management, data was gathered through an anonymous online survey and follow up interviews. The data was gathered through voluntary participation which may have resulted in a narrow set of perceptions on knowledge transfer being collected; however, it was assumed that an understanding of perceptions could be established and cross referenced with the literature for anomalies.

Limitations

This case study looked at CSIRO Climate Adaptation researchers' knowledge transfer perceptions and practices, and therefore generalisations are limited. In addition the case study only explores one side of the knowledge transfer process and therefore may not paint a balanced or fair portrait of the system as a whole. While all knowledge transfer processes are different, this study is comparable to similar case studies undertaken elsewhere and can therefore provide some insights into the science/decision maker interface. Additional research into the perspectives of decision makers in Australian Government departments would provide a more holistic picture of the knowledge transfer process.

Overview of this thesis

This chapter, chapter one, sets the scene for the thesis. Chapter two explores the relevant literature and focuses on the background of the issues, identifying what makes knowledge useable for decision makers, exploring barriers to knowledge transfer and examining international best practice in knowledge transfer.

Chapter three outlines the research method applied to the case study and describes the selected interviewing and data processing techniques used. The survey and interview data is analysed, interpreted, evaluated and discussed in chapter four.

The final chapter, chapter five, presents the conclusions drawn from this research and provides recommendations for improving knowledge transfer between CSIRO and Australian Government departments, as well as suggestions for further research.

2. Literature Review

Introduction

CSIRO is Australia's national science agency with a strategic applied research mandate under legislation, and has a responsibility to provide knowledge for decision makers, particularly in government. In order for CSIRO researchers to provide useful knowledge for decision making it is important to understand what information is useful to Government decision makers, and what barriers exist in knowledge transfer. To date little is known, particularly in the Australian context, about the transfer of science knowledge into policy decision making (McNie, 2007). This study aims to explore and describe the knowledge transfer practices between Australia's Research and Development organisation, CSIRO, and its government, from the perspective of a small subset of researchers within CSIRO's Climate Adaptation Flagship.

This chapter will explore current understandings of what decision makers consider to be useful information and how understandings differ from a research perspective of usefulness. The review will investigate barriers to knowledge transfer and knowledge uptake, and identify processes of best practice. In addition, the impact of uncertainty on knowledge transfer will be explored due to its importance for decision making on climate change issues.

A Diabolical Problem

Ross Garnaut calls climate change a "diabolical policy problem" which reinforces the need for CSIRO researchers to transfer knowledge effectively for decision making (Garnaut, 2008, p. xviii). Science is often thought to have the answers to society's problems and questions; however, Anand (2000) suggests that decision-making without scientific evidence, or well-defined probabilities, is far from unusual. To further complicate the matter there is a lack of clarity among researchers on what approach to take in reconciling the supply (research) and demand (decision making) of information (McNie, 2007).

Around the globe millions of dollars are spent on climate adaptation research; however, evidence is lacking on whether the knowledge gathered is useful for decision makers (California Climate Portal, 2009). Some argue that politics gets in the way of science; while others think it is just as valid to suggest that researchers have failed to provide information in a useable or timely manner for decision makers. Sarewitz and Pielke (2007) have argued that science is always politicized, and that the real-world challenge is to provide useable knowledge for decision makers. To this end, the literature review will inform the following study of CSIRO researchers and their perceptions of their interactions with Australian Government departments.

Useable Knowledge

Is all information useable?

In order for information to be of use beyond the scientific community, researchers must engage with the community so as not to conduct research in a societal vacuum (Dilling, 2007). In addition, research suggests that for improved decision making in society, science and science advice should be sought and provided early in the decision making process (Socci, 2000; Keough, 2002). This has lead to a call for improving science literacy among decision makers, as increasingly science and technology have an impact on almost every aspect of society.

Until relatively recently, science was seen as being undertaken for its own sake, with the implication that useable knowledge would emerge from research unfettered by considerations of use (Stokes, 1997). This 'linear model' or 'loading dock' approach to science, without thought of practical ends, and then expecting it to be useful to others, is not usually effective (Dilling, 2007). Van Kerkhoff (2008) pointed out that science can no longer be justified purely as the search for knowledge; it must be relevant and effective in addressing the needs and expectations of society.

Previous research has shown that not all science knowledge is useful to decision makers, and that usefulness is often determined by the link to or participation of the wider community (McNie, 2007; Sarewitz and Pielke, 2007). This is particularly true of

information for policy makers, who are making decisions for and on behalf of society. In fact, some researchers suggest the production and volume of scientific information has outrun its effectiveness for society (McNie, 2007). For example, refining the projected sea level rise to the nearest centimetre does not necessarily improve the usefulness of the information for decision making, whereas an economic analysis of storm surge impact might provide more relevant knowledge. This message is taken further by other researchers, who argue that we could be using existing knowledge better and that some scientists "may simply be producing too much of the wrong kind of information" (McNie, 2007, p.17).

Criteria for useable knowledge

So what makes knowledge useable for decision makers, given that most people recognise that more information does not necessarily lead to better decision making? As pointed out by Andrey and Mortsch (2000) just because information is 'going out', does not mean that it is 'going in'. What is important is whether understanding has been improved, people's attitudes have been changed, and whether decision makers have useable information. Need, appropriateness, timeliness, useability and how the information is communicated all affect the information's usefulness to a decision maker according to Sarewitz and Pielke (2007). McNie (2007) has a slightly different perspective suggesting that useful information expands alternatives, clarifies choice and enables policy makers to achieve desired outcomes.

Useful information has been described by Cash and colleagues as salient, credible and legitimate (Cash, Clark, Alcock, Dickson, Eckely, Guston, Jager and Mitchell, 2003). Others have described useable information as having values consistent with a desired situation, meaning that useful information is more than content, it is the product of an effective process (McNie, 2007). Sarewitz and Pielke (2007) have expanded this idea, suggesting that to produce ''science that is maximally responsive to the needs and values of those who may have a stake in the outcomes of the research'' and to create ''useable science'' new engagement pathways need to be discovered (p.9). Dilling (2007) proposed

that "information that is created and disseminated without awareness of and engagement with intended users generally fails to be useable" (p.49).

So in order to better serve decision makers, McNie (2007) suggested that "the connections or linkages between both the supply of, and demand for, scientific information need to be enhanced so that scientists produce information that is both needed and used by decision makers in their policy decisions" (p.18). Therefore useable knowledge should be understandable to users, and should be available at the times and places it is needed (Dilling, 2007). For example, information that takes years to produce is not particularly useful to a decision maker who operates on much shorter time frames, where a month can seem like a long time.

Not only does information need to be available, it also needs to be communicated. Communication involves imparting knowledge with the intent of raising awareness, promoting understanding and changing behaviour. In many contexts communication is thought to be effective only when changes in awareness and understanding result in attitudinal adjustments and/or improve the basis upon which decisions are made (Andrey and Mortsch, 2000).

In order to improve the basis upon which decisions are made, decision makers need to be able to assess the information provided. Maxim and van der Sluijs (2007) have suggested six knowledge quality criteria for assessing information, which are:

- reliability of the information – it must be based on all available scientific knowledge;
- robustness of the information – it must take into account criticism;
- use of the information produced by other stakeholders;
- relevancy of the arguments for issue under debate;
- logical coherence of the discourse; and
- legitimacy of the information source.

For information to be legitimate, those that produce it need to be perceived to be free from political suasion or bias and to have ''the interests of the user in mind'' (McNie, 2007, p.20). For CSIRO this is particularly important in its role as Australia's science advisor.

McNie (2007) added further criteria for assessing information, suggesting that it needs to be salient, meaning the information "considers regulatory and legal constraints; the values and beliefs of stakeholders; the political landscape; and how the information is communicated and presented, among other considerations" (p.20). Therefore information provided must take into account existing policy and decision-making processes.

This idea of taking into account existing policy and processes links to Cash *et al.*'s (2003) suggestion that the attributes of useable information can only emerge from close and continual interaction between producers and users of information. Others, Sarewitz and Pielke (2007) and Pielke *et al.* (2000), argued that for effective integration of science and decision making there needs to be a tight coupling among research, communication, and use. However McNie (2007), referencing Garvin (2001), pointed out that this coupling can suffer from 'epistemological differences', suggesting that science and policy are culturally distinct, having different ways to define, produce, justify and value useable knowledge.

In order to improve policy decisions science must therefore be applied in a manner that is accountable, transparent, thorough, impartial, salient and credible. In the case of climate change and climate adaptation, researchers must also provide information, presented in a useable fashion, on what is known, what is not known, and the extent of the uncertainties and risks involved in various alternatives (Keough, 2002).

Science's role in decision making

While the previous section outlined what makes information useful, one must also consider that science is not the only source of knowledge for decision making in government. Decision makers must consider a wide range of inputs including culture, history, public awareness, self-interest, interest groups, and power relationships (Dessai and Hulme, 2004). Decision makers exercise their legitimate role in weighing up these multiple inputs and to make choices (Keough, 2000). Decision makers are influenced by social, economic and

other political considerations when forming policy. In fact many argue that policy should be influenced by these multiple considerations in order to formulate good policy, and that science advice should only be part of this process (Keough, 2002).

Governmental decision making involves many trade-offs, particularly when considering climate issues. However, Pielke (2002) has argued that some scientists still believe that 'science' alone provides a sufficient basis for decision making. Nelson, Howden & Stafford Smith (2008) disagree, suggesting that researchers understand that decision makers need to consider multiple and changing interests and values, including different temporal and spatial scales, and inter and intra generation equity. Nelson *et al.* (2008) go on to suggest that the real problem for researchers is how to inform decision makers by addressing knowledge gaps and discrepancies to achieve societal goals.

Pielke (2007) has suggested that scientists seeking to play a positive role in policy decision making have to choose what role or roles to play; the Pure Scientist, Science Arbiter, Issue Advocate or Honest Broker of Policy Alternatives. Pielke indicated that all four roles are critically important and necessary for a functioning democracy.

Despite the role of science and scientists in decision making, decision makers often feel that they are not being provided with sufficient information to meet existing issues. Tribbia and Moser (2008) also note that decision makers see the lack of resources, staff, and time as major 'hurdles' or barriers to informing themselves about science issues such as climate change and adaptation challenges.

Barriers to Knowledge Transfer

The Communication / Learning Gap

Decision makers have, in part, found it increasingly difficult to incorporate science into decision making due to the rapid increase in the quantity of information available. Science knowledge is now produced and communicated not only by research organisations and universities, but also by other groups, such as industry, NGOs and the media. While this flood of knowledge is in some respects increasing the general understanding of science, it is

also calling into question what is 'good' science. Some of the more easily understood information may not be the most objective, yet can play a key role in forming opinions and misconceptions when considering the constructivist view of learning, which suggests that individuals and society develop an understanding of an issue and generate knowledge from all their experiences (Maxim and van der Sluijs, 2007).

This constructivist view also calls into question the assumption that providing information and teaching the public about science will ensure a better understanding of the issues and lead to improved decision making. While at the same time psychology literature has highlighted the limitations of the 'deficit model' of knowledge transfer, whereby a researcher views a decision maker as an empty vessel to be filled with knowledge. Wynne (1996) suggests that personal and societal values and norms influence individuals' construction of provided information. In addition to their own values, awareness and experience this will influence an individual's decision making choices.

However, there continues to be calls for a more informed, scientifically literate public in order to improve knowledge transfer. Brand and Karvonen (2007) argued that if decision makers had a basic understanding of the science that they would be better placed to receive more detailed information for decision making. This increased understanding would, in part, alleviate Pielke and Conant's (2003) concern that "experience is essential for effective decision-making, and most decision-makers have little experience using models or their products" (p.1356). Even something as common as weather forecasts can create confusion and misunderstanding in the general public, where a large percentage of the population do not understand percentages, i.e. 80% chance of rain does not necessarily mean that it will rain (Wardekker *et al.*, 2008).

Another communication barrier to knowledge uptake is 'cognitive dissonance'. Cognitive dissonance is the theory that information is only accepted and integrated if it is consistent with someone's behaviours and beliefs; if it is not, then a person will distance themselves from the information. Communicators of information need to be aware of people's beliefs, values and norms before trying to provide radically new information. This is particularly important when providing information to decision makers, as the dissonance between new

information and existing beliefs and values will slow down or block science assimilation into policy (Bradshaw and Borchers, 2000).

This communication barrier also relates to Adger *et al*'s (2007) research, which monitored peoples' reaction to the climate change movie The Day after Tomorrow; this showed that fear and guilt do not motivate people for long and therefore are not a pathway to engaging with decision makers with regard to climate adaptation options. The research demonstrated that shortly after seeing the movie people had a higher awareness and willingness to change their behaviour in order to become more environmentally friendly, but that it did not take long for the pressures of everyday life to supersede these concerns.

Science and Decision Makers' Communication Gap

The United Nation's Agenda 21 programme has also highlighted the communication gap between scientists and decision makers. Obdeijn and Kok (2000) suggested that this is driven by the discrepancy between the knowledge needs of stakeholders and the knowledge produced by science. Socci (2000) highlighted the complexities in this communication mismatch, suggesting that the traditional science community of research organisations and academics had expressed an "unwillingness or indifference ... to communicate science clearly and effectively to decision-makers and other non-scientists" (p.P2:2). Pielke (2002) also noted that this has been a key criticism of the IPCC reports, that they only "assess knowledge of climate-change science, impacts and economics, but not their policy significance" (p.368). This then leaves the decision makers "forced to rely on interpretations (and misinterpretations) provided by corporations, government agencies or interest groups" (p.368).

Closer to home, Australia's Council of Australian Governments (COAG) National Climate Adaptation Framework (2007) drew attention to the knowledge gap for decision making, suggesting the "need to improve the synthesis and dissemination of information for decision-makers" (p.6). COAG recommended that researchers focus on the needs of decision makers and that information be tailored to user needs to enable effective adaptation. At the same time COAG acknowledged that "Australia's scientists have

generated a base of information about how the climate is changing", although it advocated that "improved information" is required for decision makers (p.7).

To improve communication, one must look at the other barriers to knowledge transfer and generation of useable knowledge. Of the many barriers to knowledge transfer on climate adaptation issues, uncertainty in all its forms seems to be the biggest stumbling block. Carpenter (2002) succinctly suggested that "science is as much about clear articulation of what we do not know, and what we can do about it, as it is about the known" (p.2070).

Uncertainty

Uncertainty and Decision Making

Making decisions is about looking towards the future and trying to determine which path to take to achieve the most desirable outcome. Decision makers in governments and other organisations have traditionally looked to science and technology to quantify and if possible reduce uncertainties about the future, in order to determine which path or paths to take to achieve the preferred outcome for society (Pielke *et al*, 2007).

Uncertainty is a broad and elusive concept and is closely linked to philosophical and sociological concepts of knowledge. Essentially uncertainty can be understood to be a perceived lack of knowledge for the purposes of making a 'correct' decision. A correct decision is one where you achieve the outcomes you expected from your actions. This idea of a correct decision is also subjective, as different individuals or groups will have different values or perceptions regarding the issues (Bammer, 2005).

Uncertainty is a feature of every decision. Even if all scientific uncertainties could be removed, all decisions potentially have multiple options and outcomes. This can be due to a lack of time or resources to fully explore an issue, or the impossibility of doing that even if information is available. Therefore decision makers seek information to clarify their options and possible pathways to preferred outcomes.

For climate issues in particular, Bradshaw and Borchers (2000) concur with Garnaut's 'diabolical policy problem' assessment, suggesting that the complexity of the climate system and human choices means that science cannot always provide all of the answers. Any complex issue or problem will have many unknowns, with some unknowns resulting

from resource limitations on research, some from methodological limitations, and some being simply unknowable (Bammer, 2005). It is possible for research to reduce some of the uncertainty over time; however, there are some uncertainties that it is not possible to eliminate. There should, therefore, be a shift in thinking about uncertainties; instead of focusing solely on reducing them, researchers should also work on communicating what is known and what is unknown, and work on providing options for decision makers (Langsdale, 2008).

Types of Uncertainty

Uncertainty can come in many forms: in relation to what is known, the future, or the unknown unknowns, often referred to as ignorance (Wynne, 1992) or deep uncertainty (Kandlikar *et al*, 2005). Dessai and Hulme (2004) distinguish epistemic or reducible uncertainty, from stochastic or irreducible uncertainty. Epistemic uncertainty originates from incomplete knowledge of processes that influence events. For example, in climate modelling, epistemic uncertainty relates to gaps in the model's structure or data. The stochastic or irreducible uncertainty stems from the unknown unknowns such as human behaviour, where no amount of research will generate absolute predictions (Langsdale, 2008). In particular it is stochastic uncertainty that highlights the misconception that uncertainty about climate change and adaptation options can be completely reduced by more science.

Scientific uncertainties, in part, relate to the spatial and temporal uncertainties associated with climate forecasts (Adger *et al*, 2007). Scale uncertainty relates to the substantially different impacts on the data gathered for scenarios; what is collected for a broad scale scenario could potentially have a very different outcome at a local scale. For example, it would be meaningless to provide weather forecasting for a State like NSW as a whole, which is why weather forecasts are broken down into regions. A city worker in Sydney wants to know if they should carry an umbrella in Sydney, for which a State wide rainfall likelihood is no help (Duerden, 2004).

In addition, the responses of society to climate change represent a big unknown, with effective adaptation actions depending on the "future—unknown—state of the world" (Adger, Arnell & Tompkins, 2005, P.81). The future of the world is uncertain, because all

outcomes cannot be known. Even if science had all the answers, decision making would also need to take into account other factors in order to achieve a desirable future, such as what Australia's population should be, our standard of living or our role in the international arena.

Uncertainty is also created due to the different values and beliefs of individuals and societies; in particular these differing, and often conflicting, values and beliefs will create different futures or outcomes. These diverse sources of uncertainty make it difficult to prioritise options for the future and therefore make decisions or policy responses. Both researchers and decision makers have highlighted that there is a key knowledge gap in how to communicate the nature and interrelatedness of these uncertainties for decision making.

Risk versus Uncertainty

Uncertainty particularly impacts on decision making in relation to risk. In climate change assessments, risks stem from the consequences of a changing climate and can include sea level rise, increased storm events, long and more intense heatwaves and prolonged drought. As mentioned earlier there is a perception that uncertainty is unacceptable to decision makers; however, it remains that engineers and other professionals are familiar with working in conditions of uncertainty. The combination of uncertainty and risk can stagnate decisions in government, with politicians and the public tending to be risk averse, regarding "uncertainty as not only unacceptable, but also as someone else's fault"(Clark, 2002, as cited in Langsdale, 2008).

The United Nations' report *Living with Risk* suggested that levels of risk awareness depend largely on the quantity and quality of available information and on the difference in people's perceptions of risk. Maxim and van der Sluijs (2007), agreed suggesting that "scientific risk evidence received from decision-makers strongly depends on the economic and social context in which the risk is identified" (p.5). Wynne (1992) highlighted that only looking at uncertainty in science knowledge ignores the influence of political and societal contexts associated with risk.

Not only does the perception of risk change with the available information, but how we make decisions has radically changed over time, with early humans learning through physical experience, whether their own or someone they knew directly (Good, 2000). Today it is possible to learn without directly experiencing what you are learning about. Although Marx *et al.* (2007) have argued that individuals and groups are still motivated more by "affective and experiential" information than statistical information when they decide what risks to pay attention to and when to take action (p.11). Marx *et al.* (2007) go on to suggest "that many, if not most decisions and actions under risk and uncertainty are driven by how we feel about the situation" (p. 12).

Living with Uncertainty

Socci (2000) proposed that research communities are unwilling or indifferent to communicating science. In addition Marx *et al* (2000) suggested, that there are other issues such as how we feel which impact on the issue of uncertainty. Climate change represents many challenges for effective communication, including the various uncertainties, both science related and in the socio-economic sphere. Climate change also lacks immediacy due to the long time frames involved. Additionally, the language of science can make it difficult for decision makers and the public to understand and create an informed opinion.

Many scientists believe that the general public are unable to conceptualise uncertainty and therefore that communicating uncertainty will only lead to an increasing distrust of science (Bradshaw and Borchers, 2000). However Kasemir *et al* (2003) have shown through their research that the general public in focus groups can successfully take part in debates about complex environmental issues that are blurred by uncertainties. Wardekker *et al* (2008) outlined that there is a need for clear and responsible communication of uncertainties even though it is difficult and not always appreciated.

McNie (2007) identified that, despite uncertainty being prevalent in scientific research, scientists have difficulty in translating the concept of uncertainty into terms that the public, including the decision maker, understand. For decision makers, Bradshaw and Borchers (2000) attribute this difficulty to differences in ''distinct behaviours and attributes'' between science and government (p.2).

Decision Uncertainty

Even if uncertainty is high, decision uncertainty does not have to be debilitating. The philosopher John Dewey (1960) believed that people are seeking 'security in the results of action', but that every day people make choices without a full knowledge and understanding of all the possible outcomes and consequences of their choices and actions. As Willows and Connell (2003) pointed out "a decision-maker simply needs to know whether one option is better than another (the rank order of options)" (p.54). What this means is that, while the science might be uncertain, it does not mean that a decision maker is unable to form an opinion and undertake action. Therefore the role of the researcher is to communicate the available options and their possible outcomes to the decision maker. This is consistent with Pielke's (2007) idea of an Honest Broker.

While uncertainty is a legitimate concern, it is also used as an excuse to delay decision making. Shackley and Wynne (1996) suggested that a decision makers' call to reduce uncertainty may be in order to locate the responsibility for tackling the issue of climate change within the science rather than the policy domain. This view is held by some researchers who, as highlighted by Andrey and Mortsch (2000), think that "uncertainty has helped to foster a wait-and-see attitude to decision making, and has facilitated the skeptics' responses to climate change" (p.WP3). Climate sceptics often highlight the fact that scientists are uncertain about the realities of climate change. This is usually due to the fact that science is made up of individual scientists; as Henry Bauer emphasised, science is "a mosaic of the beliefs of many little scientific groups". As in the rest of society, scientists are individuals with their own set of values and beliefs, which they can not help but bring into their research (Pielke, 2002).

As highlighted by the Stern Review (2006), no one can predict the consequences of climate change with complete certainty, although enough is already known to understand the risks. Consequently, uncertainty should not be used as a justification for not taking action. In fact Stern went on to say that uncertainty is an argument for a more, not less, demanding goal. Dessai *et al.* (2007) also argued that current information should provide decision makers with enough knowledge to take specific policy actions.

Therefore, is uncertainty really a barrier to decision makers? Decision makers have been known to suggest that scientific uncertainty prevents or delays decisions (Langsdale, 2008; Bradshaw and Borchers, 2000), suggesting that they need reliable, robust, and hence certain scientific knowledge to make a decision (Langsdale, 2008). However people, including decision makers, make decisions under uncertainty all the time. People make choices without knowing all the aspects of their choice, from crossing the street, to what food to buy. These decisions or futures are also affected by the choices and actions of others, which can lead to unexpected outcomes which people have little control over, such as being hit by a car while crossing the street, or suffering from food poisoning due to poor hygiene practices.

In fact, Ludwig, Hilborn and Walters (1993) pointed out that there is a well developed theory of decision-making under uncertainty, and that history has demonstrated that it is possible to make effective policies under conditions of uncertainty. Ludwig *et al.* (1993) argued that most principles of decision-making under uncertainty are simply common sense. This is contradicted by Peterson, Cumming and Carpenter (2003) who suggested that uncertainty can lead to inaction or 'paralysis by analysis' for decision makers. Peterson *et al.* (2003) recommended that uncertainty should be viewed as an opportunity for action, since no one knows what the future might bring, and that decision makers should be encouraged to try something new and see if it works.

Communicating Uncertainty

Not all decision makers view uncertainty as an obstacle. In Tribbia and Moser's (2008) study of climate change and coastal managers, they found that respondents did not consider uncertainty in climate change science to be a significant obstacle to taking action on the issue. The case study went on to highlight that coastal managers rarely deal with things that are certain, and that they do not expect certainty of climate information in order to make decisions.

The most important finding of Tribbia and Moser's (2008) study was that scientific information, even if uncertain, needs to be translated or communicated in management-relevant variables or metrics. Bradshaw and Borchers (2000) suggested that one way of

bridging this communication gap is to realign the definition of scientific uncertainty as perceived by the public and policy makers with that of the science community. This strategy would need to recognise that:

- science and knowledge are intrinsically uncertain, with new information continually altering our perceptions and beliefs;
- decisions based on scientific information must be made in a context of uncertainty; and
- faster and better science as an adequate basis for policy formulation is inconsistent with the nature of scientific inquiry and resilient policy formulation.

Langsdale (2008) also suggested three challenges in communicating uncertainty: intolerance of uncertainty, lack of attention to the amount of uncertainty in modelled results, and omission of elements that contain uncertainty. However, other researchers, such as Wardekker *et al.* (2008), proposed that the different perceptions of uncertainty of researchers and decision makers would be better dealt with in communication strategies, highlighting that information needs to be tailored to end users of the information, particularly the decision problem that the user faces. Like Pielke (2001), Wardekker *et al.* did not suggest that researchers should tell policy makers what to do, but instead should provide them with a full distribution of useful insights or options to help make their decisions.

Pielke (2001) takes this a step further, suggesting that consensus science can only provide an illusion of certainty and can in fact constrain decision makers' options. Keough (2002) agreed, suggesting that it is usually possible to drawn more than one legitimate set of conclusions from the same set of facts, going on to say that:

> "science advisors may express a preferred interpretation, but they should be clear if it is not the only one. Otherwise, they have failed to provide the best science advice" (p. 107).

Processing Uncertainty

Socci (2001) showed that some uncertainties can be eliminated for decisions makers by improved communication about researchers' "reliance on statistical methods and criteria for expressing confidence, (certainty) or lack of confidence" (p. P2.2). Socci argued that decision makers find current communication practices unfamiliar and highly confusing. A good example of this comes from Brewer and Gross (2003), who highlighted that "regular exposure to probabilistic ideas (e.g., weather forecasts, lotteries) has not provided much of a basis for public appreciation of uncertainty in ecological forecasts" (p. 3). Real advances in the public understanding of weather forecasting have come from satellite imagery, allowing people to picture the weather. Brewer and Gross (2003) went on to suggest that visual or other devices that promote understanding have the potential to affect decision making on environmental issues.

In order to communicate climate information, particularly uncertainty, researchers need to be aware of how people learn and process information. Marx *et al* (2007) highlighted that while people process uncertainty information in different ways, most researchers communicating climate information assume people process analytically. In fact, people also rely on experiential processing, i.e. comparing new information to what they already know and have observed themselves. Translating statistical information into concrete (vicarious) experience helps facilitate intuitive understanding of probabilistic information. Marx *et al.* suggested that, by sharing experiences through group discussions and other processes, it is possible for decision makers to gain a richer understanding of decisions and possible outcomes that is not provided by an analytic understanding.

Wardekker *et al.* (2008) also suggested, that people are better at hearing, reading, using and remembering risk information described in words, rather than in numbers. However, words can have different meaning for different people and also are not as precise as numbers when giving a range of possibilities. Kandlikar *et al.* (2005) proposed that there were issues with "linguistic imprecision", that the use of terms such as "more compelling or likely" and "equal footing" would be interpreted differently by different people (p. 450). However Wardekker *et al.* highlighted that communicating infrequent or stand alone events is much harder than more frequent activities such as rain. This has implications for climate

communication as we are only starting to experience climate impacts now and people can not visualise the impact.

In fact, research has shown that analytical decision making is typically at a disadvantage when people have a choice between it and concrete personal experience (Marx *et al.*, 2007). This can be demonstrated in everyday life when people make decisions for which they do not understand the full range of outcomes; they base their decision on past experience, such as choosing to not to wear a bicycle helmet or choosing to buy a lottery ticket. People purchase a lottery ticket despite the extremely low chance of obtaining the winning ticket; yet people who choose not to wear a helmet assume that falling off the bicycle (a much higher probability event) will not occur. Marx *et al.* (2007) suggested that "the way in which information is communicated, and the processes that this communication triggers, are important determinants in the outcome of decisions that involve small probability events" (p.10).

Communicating Uncertainty in the Modern World

A recent change in communication practices has centred around media dependency theory, which suggests that we come to 'know' people, issues and realities that we have not directly experienced. This has greater influence than ever before as people have fewer 'word of mouth' interactions and social ties, with more people in urban-industrial societies becoming dependent on mass communications for information needed to make many kinds of decisions (Good, 2000). Good (2000) also highlighted that "individuals do not process information in a vacuum", that perception is often created by social interactions, values and cultural identity rather than individual attitudes and knowledge (p. B2:28). The implication is that the links and ties of individuals are as important as the information or knowledge flow between them.

This understanding of how people absorb information and make decisions on risk and climate change suggests a possible pathway for knowledge transfer through group discussions and the sharing of personal experiences, otherwise known as participatory action research. However, vicarious experience is not as powerful as personal experience

due to the lack of strong emotion produced from experiencing the positive or negative outcomes by the individual (Marx *et al*, 2007).

Another way of communicating uncertainty in climate adaptation options is through scenarios. This allows decision makers to get a picture of the future and what decision options might lead to that outcome. However, it is also possible for decision makers to interpret scenarios as literal predictions of the future (Shackley and Wynne, 1996), whereas researchers usually understand that scenarios are simply alternative ways in which the future might play out. Scenarios as a way of transferring knowledge are discussed in more detail later in this chapter.

While researchers can and should improve their communication skills, they also need to make decision makers and the public in general aware that science can not, and never will be able to, remove all uncertainty surrounding complex issues such as climate change.

Apart from uncertainty, there are many other barriers to transferring knowledge including: competing priorities, time and capacity constraints. Decision makers also find some of the available information a barrier to knowledge uptake, with many decision makers not having the time, inclination or the ability to read science journals or understand science jargon (McNie, 2007). These are all major barriers to accessing information for decision makers.

Access to Information

As mentioned above, while uncertainty is a barrier to knowledge transfer, so is access to information. This is an issue in multiple parts, with not enough information on some issues, too much on others, information provided in inappropriate formats, and difficulties in knowing which information to trust or how to access it. Decision makers have highlighted that gaining access to the right information is often the hardest part of the decision making process (Holmes and Clark, 2008).

There are many reasons for this information disconnect between researchers and decision makers. In part it is driven by different cultures and reward structures, with researchers driven to publish in scientific journals which decision makers have either little interest accessing or trouble interpreting the science's relevance to them. Also researchers have

traditionally had little incentive to communicate to non-scientists, although this is now changing to some extent through the research grant process and a requirement for societal impact. Tribbia and Moser (2008) suggested that researchers "frequently simply assume that their information and knowledge is reliable and useful without necessarily checking this assumption against reality" (p.316).

Tribbia and Moser's (2008) case study highlighted that over 70% of the 132 coastal management decision makers in their study either never used or rarely used the typical outlets of scientific information (primarily peer-reviewed journals). Holmes and Clark (2008) also found that decision makers did not use journal papers as sources of information. Decision makers found journal papers to be "too focused, technical and detailed" for their needs, and indicated that they did not have the time to read the number of papers needed to develop an overall understanding of an issue (p.706). The exception to this was review or synthesis papers that explored the current state of knowledge on an issue. Decision makers viewed these as valuable sources of information (Holmes and Clark, 2008).

Quality of information has been identified as one of the most significant issues around knowledge transfer. Tribbia and Moser's (2008) case study highlighted that, while most participants knew there were reams of information to be found on the internet, the quality of the information was hard for non-experts to assess. This could explain why most participants' preferred channel for communication was interpersonal contacts. In Holmes and Clark's (2008) study some interviewees expressed a complementary desire for written material to be accompanied by an assessment of its reliability, either a ranking or a stamp, much like Australians are now used to the Heart Foundation's tick of approval. CSIRO perceive that the CSIRO brand or logo fulfils a similar role to the Heart Foundation tick (CSIRO Annual Report 2006-2007).

The over supply of information is not restricted to the internet. There are currently multiple sources of information for decision makers on climate adaptation issues which include, but not limited to, policy documents, the internet, television, newspapers, and popular science journals. These competing sources of information have the potential to relegate peer review science if they better suit decision makers' needs and time frames (Bray, 2000).

These forms of knowledge transfer also have far greater societal influence than traditional peer reviewed journals (Dilling, 2007).

While decision makers now have multiple ways to source science information, there is still a demand for advice from experts. Holmes and Clark's (2008) study highlighted the need for a searchable database of information or a register of experts, which decision makers could use when they sought information or advice. This interaction between researchers and decision makers is not without its problems either, such as the 'capture', or exclusive use, of a knowledge expert which can lead to the transfer of opinions rather than independent science advice.

Cultural and Knowledge Systems

In addition to the barriers of uncertainty and access to information, the different cultures and knowledge systems of researchers and decision makers can obstruct knowledge transfer. In order to successfully transfer knowledge it helps to understand the knowledge systems of your intended target; similarly it is important for recipients of science information to have an understanding of scientific culture. Researchers and government decision makers have often shown a lack of understanding of the other's knowledge systems (NcNie 2007). McNie also suggested that it is a lack of understanding of these differences that have resulted in an inability to create mutual trust and respect between scientists and decision makers.

Cortner (2000) suggested that science has a culture all of its own, which can make researchers "biased, irrational, and emotional creatures" when dispensing knowledge (p.23). Cortner went on to argue that "more attention needs to be paid to understanding the culture of science and bridging the differences between citizens and scientists, and science and policy" (p.29). The concept of cultural barriers is explored in this study, from the researchers' perspective.

Cultural barriers are not limited to the gap between researchers and decision makers; there are also cultural barriers within the science community as well. These internal barriers can create obstacles for the transfer of knowledge, such as the tensions created by reward

structures for researcher publishing in journals and engaging with decision makers. Individual promotions in research organisations are often based on publications in academic journals, presentations at conferences and the number of PhD students successfully graduated. By contrast, time consuming engagement activities, such as developing relationships with decision makers and subsequent policy relevant information briefs, are typically not counted. This can result in research staff being unwilling to undertake participatory, multidisciplinary or use-inspired research. NcNie (2007) argued that decision makers face similar barriers, being "reluctant to use more participatory research approaches because of the increased costs and longer time required for such processes" (p.24). However, many decision makers and researchers see the benefit of gaining "an understanding of their differing perspectives and approaches" (Keough, 2000, p.6).

Holmes and Clark's 2008 study highlighted this tension, with participants suggesting the culture of science actively provided a disincentive for researchers to engage in knowledge transfer with decision makers, stating "that a researcher's peer group may look down on researchers who communicate their work to lay audiences, and time spent on interpretation work may well be at the expense of the publication record that a researcher requires to progress his or her career" (p.708). One solution identified in the literature was the possibility of engaging interpreters or boundary individuals to assist in the transfer of knowledge between researchers and decision makers. However, Holmes and Clark (2008) pointed out that "consideration also needs to be given to defining and enabling careers for interpreters in order to attract high calibre individuals with the necessary skills" (p.708).

Capacity

The cultural barriers discussed above are linked to a lack of capacity for processing research in government departments. Tribbia and Moser (2008) have pointed out that most decision makers have multiple competing priorities in their day jobs and that these "challenges leave them with little extra capacity to become knowledgeable about climate change or begin developing long-term adaptation strategies" (p.316). In addition Tribbia

and Moser highlighted that decision makers felt that they had insufficient staff resources to gather and process relevant information on climate change issues.

One way of countering this lack of capacity, suggested by Keough (2000), in a review presented to the Canadian government, was that governments needed to ensure that departments had sufficient internal resources for supporting policy research, to assess, translate and communicate science for policy to underpin the science advisory process. Keough suggested that government departments should provide professional development/training to government decision makers and scientists, to improve science communication and the use of science advice in policy making.

While the literature suggests that research organisations like CSIRO should improve their processes of communication and knowledge transfer, the spotlight should also be pointed at government becoming better at engaging with researchers and participating in the knowledge transfer process. Keough (2002) argued that government must improve its "absorptive capacity for science" by creating the "in-house capacity required to assimilate, interpret and extrapolate the knowledge" (p.106). Keough suggested the best way forward would be to "foster the interchange of scientists among government, academe and the private sector" (p.106).

Time Scales and Communication Formats

A further barrier to knowledge transfer is the mismatch in time scales, with a lack of timeliness of research often a reason given by decision makers for the science policy lag. Not only does research often take several years to develop an outcome, where a decision maker may only have a couple of weeks, there is also a significant time lag for the assimilation of scientific findings into society (Bradshaw and Borchers 2000).

Time scales also create a barrier to knowledge transfer between decision makers and researchers in two ways: delivery of the information and observable results. In terms of information transfer, research and decision making are often operating on different timelines (Dessai and Hulme, 2004). While often appearing slow and bureaucratic, planning horizons in government can operate quite quickly at a weekly to monthly scale

and may not go longer than a year or two (Van Kerkhoff, 2008). In science, research can take years if not decades to yield a result.

This mismatch in time frames can be highlighted in the rate of outputs. A researcher would be considered to have a high rate of output if they published 4 to 5 journal papers in a year, whereas a governmental advisor might be expected to produce 4 to 5 reports in a week (Von Kerkhoff, 2008). Godard (1992) highlighted that these mismatches in timeframes can also lead to decision makers making maladjusted responses particularly when "environmental systems evolve faster than the knowledge about them; political will develops quicker than the scientific information; laws run ahead of - or lag behind - the development of technologies that are necessary to implement them" (p.246).

Language and Two Way Communication

Part of successful knowledge transfer is about being understood, which means providing the information in an accessible format and using language that your audience already understands (McNie, 2007). Language and words are fundamental to how we communicate, and there is extensive literature on how best to communicate and, in particular, how to overcome language barriers. Some include: a clear statement of goals, substituting technical terms with plain English, avoiding jargon, and explaining necessary scientific terms (Andrey and Mortsch, 2000; Scott, 2000).

Tribbia and Moser (2008) have advocated that researchers need to develop a wider range of communication skills in general. Langsdale (2008) however has noted that communication is a two way process, that both the givers and receivers of information have a role to play in ensuring that knowledge is transferred and understood. Maxim and van der Sluijs (2007) and Obdeijn and Kok (2000) also discussed the two way nature of communication, suggesting that the communication is shaped by situations, institutions, and social structures, but it also shapes them. In this way communication can be seen as a pathway to change. Rosales (2000) highlighted that in order to do this there is a need to improve the capacity for communication between researchers and decision makers, suggesting that the "innate characteristics of science, impacts and policy need to be understood within each other's framework" (p.C2:7). Langsdale (2008) suggested that scenarios could provide a

mechanism "for presenting results in an easily understood format, while maintaining important information about the range of uncertainty and the probability" (p.28).

Trust and Legitimacy

Once communication channels have been established, and researchers and decision makers begin to understand each other, the most important barriers to knowledge transfer include relevance and legitimacy of the information and trust in its source (Glover, 2000). It is particularly important for governmental decision makers to be able to trust the accuracy and legitimacy of the information on which they make decisions, as their decisions impact on the country as a whole and often underpin the creation of its policy and laws. This relates to Sarewitz and Pielke's (2007) suggestion that the key issues for knowledge transfer are expectations and capabilities, meaning that there is a need to establish whether decision makers have reasonable expectations of what the science can deliver, and whether they can use available or potentially available information.

Trust is important is all relationships, but particularly where there is transfer of knowledge. Fischer, Shortle, O'Connor and Ward (2000) identified the growing importance of trust in knowledge transfer, outlining that researchers have traditionally argued their science theories within the science community and are now confronted with debating in public on science issues. The current practice of researchers debating in public, particularly on climate issues, has shaken the public's faith in 'experts'. The public and decision makers are now confronted with the task of choosing which experts to believe and trust (Brand and Karvonen, 2007; Tribbia and Moser, 2008).

Another modern barrier is the speed at which knowledge is generated in today's society, knowledge is now generated so quickly that it is outstripping researchers' ability to pass it on, leading Bray (2000) to suggest that we have reached a knowledge bottleneck. Bray proposed that in order to better transfer knowledge, researchers and decision makers must learn how to better cooperate and integrate. This will require that the trust has been developed first.

Pathways Forward

While many of the barriers to knowledge transfer have been highlighted above, it should also be acknowledged that researchers and decision makers are starting to find better ways to communicate. There are many suggestions for improving knowledge transfer outlined in the literature, including: capacity building; web-based clearing houses; conferences and workshops (Tribbia and Moser, 2008); improving social capital (McNie, 2007), and the creation of online tools (Bussenschutt and Pahl-Wostl, 2000). However this literature review also explored three inter-related options that are currently being used to varying degrees by CSIRO staff, including scenarios, participatory action research and boundary individuals or organisations. The first two have been well developed within CSIRO, while the concept of boundary organisations or individuals is recognised but undeveloped.

Scenarios

In an uncertain world one way to assist decision making, and planning for the future, is to extrapolate plausible futures and explore the steps to and consequences of the different actions (Feizer and Harriss, 2000; Peterson *et al*, 2003; Dessai *et al*, 2005). This process can be undertaken through the development of scenarios.

Scenarios can be a useful tool for assisting decision makers to plan for the future. In particular, Anand (2002) suggested that "when scientific knowledge about probabilities is absent, thinking about possible outcomes takes on particular significance" in order to think through the possible outcomes and impacts from a particular set of decisions (p.1839). However, some argue that scenarios for a climate adapted world are not needed for decision makers, that a strategy of resilience and adaptive management would be a preferred option (Dessai and Hulme, 2004). These authors argued that making society resilient and adaptable to current conditions would be a better strategy for near term climate change.

Hulme and Dessai (2008) suggested that, to be successful, scenarios need to be developed through negotiation with relevant stakeholders, including decision makers, but also funding agencies, social actors and variety of other sectors. Cash *et al.* (2003) argued that co-generation requires scenarios to score highly in saliency, credibility and legitimacy to retain their 'benchmark status' as desired by Government. Interestingly, and perhaps not

unexpectedly, this is a similar list of criteria to what makes knowledge useable for decision makers.

Participatory action research

Scenarios also work well in participatory action research, enabling researchers to undertake interactive sessions exploring future scenarios with decision makers. Participatory action research is a form of experimental research, where scientists work with communities, organisations and decision makers to explore an issue with the goal of improving understanding and working towards resolution of the issue. Langsdale (2008) demonstrated that during this process participants "acquired a sense of the range of uncertainty in the future scenarios, as well as the effectiveness that adaptation measures could have for a range of future conditions" (p.27). The literature suggests that this process builds trust and a shared understanding between researchers and decision makers.

Obdeijn and Kok (2000) highlighted the importance of bringing decision makers and scientists together early in the research process in order to promote successful co-production of knowledge. This is one of the core principles of participatory action research. This early proximity allows for the research outcomes to be fully embedded in the decision making process and for both researchers and decision makers to understand the differences in timing and availability of results.

Participatory action research also allows for researchers and decision makers to share knowledge, skills and personal experience, and work together on the issue. Bammer (2005) highlighted that the "importance of participatory methods is based on recognition that the various stakeholders think about the same issue differently, and that exploring, sharing, and synthesizing these different understandings enriches our knowledge about an issue, and can often trigger a new way to look at and contend with it" (p.11).

Participatory action research also helps researchers to understand how governmental decision makers operate, and how to shape the views and perceptions of decision makers, build trust and improve the decision making process (Bammer, 2005). This interaction can also assist in removing uncertainty as a barrier to knowledge transfer. However Dillings

(2007) suggested that participatory action research, or "placing the user at the centre of focus, rather than the resolution of scientific controversies, requires a change in mindset" of the researcher (p.56).

Boundary Individuals or Organisations

Another pathway identified for effective knowledge transfer is the use of boundary individuals or organisations, who communicate, translate, and interpret knowledge in order to provide useable information for decision makers (McNie, 2007). These entities have developed from the realisation, as stated previously, that decision makers do not necessarily require ''better information'' or ''more information'' about climate adaptation. Tribbia and Moser (2008) suggested that "boundary organisations have the overall dual purpose of protecting but also transcending the divide between science and practice" (p.317). Hulme and Dessai (2008) proposed that boundary individuals act as an "anchor or bridge between two social worlds", suggesting that these individuals would have an understanding of both worlds and therefore gain legitimacy in each world (p.56).

Tribbia and Moser (2008) identified four functions that boundary organisations or individuals provide, including: a convening function that brings decision makers and researchers together; a translation function to make science more understandable and therefore useable for the decision maker; a function facilitating collaboration for the co-production of knowledge (or participatory action research); and a mediation role, to ensure that the interests of all parties are fairly represented.

Boundary organisations exist because research organisations generally do not offer all four functions listed above, in particular the translation function. Decision makers generally do not provide this function either due to time and capability constraints (Tribbia and Moser, 2008). It is also possible for organisations to contain 'boundary spanning individuals', who can play an important role in boundary work. McNie (2007) suggested that we know very little about these individuals, how they do the work they do, and how to foster such attributes in others, if it is possible to do so. Boundary spanning individuals are also known as interpreters, science arbiters, honest brokers and hybrid individuals (Holmes and Clark, 2008; Pielke, 2004; Shackley and Wynne, 1996; Hulme and Dessai, 2008).

Some researchers argue that 'boundary management' actually increases the salience, credibility and legitimacy of the scientific information (McNie, 2007); others, as noted by Shackley and Wynne (1996), find that these boundary spanning individuals have to "negotiate their credibility not only among the policymakers but also within their own research communities whose work they are representing and translating" (p.276).

Summary

This literature review has developed an understanding of what is useable knowledge for decision making, including need, appropriateness, timeliness, useability and how the information is communicated. The review also identified the many complex barriers, including uncertainty, culture and knowledge systems that could impact on CSIRO's ability to communicate useable knowledge to decision makers.

CSIRO researchers' views on what makes knowledge useable, and their communication practices will be compared to views and techniques identified in the literature, including scenarios, participatory action research and boundary individuals.

Following the literature review the following questions were identified:

1. What do CSIRO researchers think is useable knowledge for the decision maker? How does this expectation differ from that in the literature?
2. What are the perceived barriers to knowledge transfer from the researchers' perspective?
3. What do the researchers' perceive to be the most effective and efficient pathways for communicating useable knowledge between CSIRO and Australian Government Departments?
4. How do these differ from pathways identified in the literature?

3. Research Method

Introduction

As highlighted in the literature review there are many complexities to transferring knowledge between researchers and decision makers, particularly in complex systems with high uncertainty, such as climate adaptation. From the literature it was identified that for information to be useful to decision makers it needs to be salient, credible and legitimate. Also identified was that science's role in decision making is to expand alternatives, clarify choice and enable decision makers to achieve desired outcomes(McNie, 2007). The literature highlighted the need for improved communication in the science community in order to effectively get their information absorbed by decision makers. One of the suggested pathways to knowledge uptake was co-creation of knowledge through participatory action research.

While a review of the literature outlined the barriers and complexities on knowledge transfer, all the case studies identified were of North American or European origin, with few Australian papers exploring the realities of this issue. There are growing calls for science to be more responsive to society, particularly in the diabolical policy problem that is climate change. Accordingly, this study explores how Australian researchers, in CSIRO's Climate Adaptation Flagship, perceive their practices of knowledge transfer to decision makers in Australian government departments. The study is concerned with CSIRO researchers' perception of current practices in knowledge transfer and perceived gaps, and how this compares with understandings taken from the literature review. Finally the study will identify possible ways to improve CSIRO's knowledge transfer in the future.

This chapter describes the approach used for this study. Outlined are the reasons for selecting study participants within CSIRO, and how data was collected through an anonymous online survey followed by interviews. The chapter concludes with observations on the limitations of the method employed.

Background

Several methods for investigating how researchers and decision makers perceive knowledge transfer processes were identified in the review of the literature. These methods included surveys, interviews, stakeholder feedback, workshops and observations. Relevant case studies include Bray and Kruck's 1998 survey exploring the interaction patterns of German policy makers and researchers, exploring their differing perspectives to climate change and how they accessed relevant information for decision making (Bray and Kruck, 2001). This example demonstrates that using surveys and interviews could gather the information required to form an understanding of the perspectives and possible cultural differences in this Australian case study.

Feagin, Orum, and Sjoberg (cited in Tellis, 1997) suggested that the "quintessential characteristic of case studies is that they strive towards a holistic understanding of cultural systems of action". In this particular study the cultural system in action is CSIRO's knowledge transfer practices. Tellis (1997) also suggested that case studies should be selected in order to maximise what can be learnt in the time available. In this case, exploring CSIRO's knowledge transfer practices is most applicable as the author already understands the culture and has built a network of relationships.

Stake (1995) outlined that all case studies must have boundaries. In order to create boundaries for this case study the sample population was limited to focus on climate adaptation issues, therefore only CSIRO's Climate Adaptation Flagship staff were approached, rather than all CSIRO staff.

The interviews following the survey were undertaken in a qualitative manner; according to Jick (1983) this convergent methodology, or triangulation of the research, can improve the understanding of the topic under investigation. Quantitative surveys have limited usefulness in exploring complex problems involving motives and actions; however, Bray and Kruck (2001) and Wardekker *et al* (2008) highlighted through their case studies that base line data can be discovered, showing trends and areas for follow up interviews undertaken through a qualitative process. Following the quantitative survey with a qualitative interview process allowed for more information to be gathered on the subject of knowledge transfer.

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4. How do these differ from pathways identified in the literature?

Methods Used

After deciding to collect data through an online survey and interviews, an email was sent to all researchers listed on the Climate Adaptation Flagship database asking if they would like to participate in the case study. The Director of the Climate Adaptation Flagship, Dr Andrew Ash, gave his permission to invite staff participation.

The interviews following the online survey followed the format that Holmes and Clark (2008) employed for their case study. Their use of semi structured interviews conducted face to face at the interviewee's place of work seemed to work well for CSIRO staff. In particular conducting the interviews at the participants' place of work proved to be appropriate as CSIRO researchers were busy and therefore it was easier to make time for the interviews within their working day. In addition, it was easier to arrange a time to meet one staff member at a time. Also meeting one-on-one, as apposed to using a focus group approach, prevented individual staff members from dominating the interview processes and potentially skewing the results by persuasion or forcing their opinion on others present. Participants were offered anonymity in reporting prior to conducting the interviews; three out of the eight staff members interviewed requested this. For consistency and due to the increasingly political nature of CSIRO's role in knowledge transfer, it was decided to make all participants anonymous in the Thesis.

The process of validation, taken from Lunter (2003), was achieved by providing the interview subjects with selected draft pages of the sub-thesis that contained quotes from their interviews. This allowed for verification of statements and provided the participants an opportunity to comment on the portrayal of their thoughts in the context of the sub-thesis. This is known as respondent validation.

Online Survey

In order to gain an understanding of the current practices and thought processes of CSIRO research staff engaging with Australian Government Departments it was felt that a voluntary anonymous online survey was an appropriate first step. As noted by Wardekker *et al* (2008) "more input can be collected in a shorter time and that more vocal participants will not drown out other participants' input" (p.629). The interviews were conducted with willing participants from the online survey.

Anonymity was important for the online survey as it allowed researchers to answer the questions freely. Given the Author's relationship to the participants, as a Project Manager within the Climate Adaptation Flagship, it was important that participants were free to answer as they wished and would not feel compelled to answer in a given way. This was achieved through voluntary participation in the anonymous online survey. With the current political nature of the climate change debate, participants' confidentiality and anonymity were judged vital for voluntary participation and unbiased answers.

The online survey, conducted with CSIRO researchers from the Climate Adaptation Flagship, was carried out over three weeks in May 2009. Follow up interviews were conducted with willing participants identified through the survey process over six weeks in July/August 2009. The delay between the online survey and follow up interviews occurred due to the increased work load of all CSIRO staff members during the end of financial year.

Survey Design

The online survey questions were formulated after exploring the literature for common issues, constraints, barriers and solutions to knowledge transfer. The online survey aimed to discover if CSIRO researchers have similar concerns and problems to those identified in the literature and as shown through case studies in other countries. See Appendix Two for the complete list of survey questions.

The survey was designed to provide information on perceptions of existing knowledge transfer and engagement practices, barriers to knowledge transfer and possible improvements to CSIRO's current practices. A series of demographic questions were also asked.

In order to test the comprehensibility and applicability of the survey, pilot surveys were completed by three colleagues within CSIRO who do not work on climate issues. These test subjects were chosen so as not to corrupt the main pool of possible respondents, since the survey was anonymous and there would have been no way of determining if participants took the survey twice. Minor changes were made to the online survey as a result of the test surveys, primarily to clarify the language of the questions in order for the respondent to better understand what the question was asking of them.

Approval was obtained from the Director and the Science Director of the Climate Adaptation Flagship to survey Flagship staff and to use the internal CSIRO network to invite participants to take part. See Appendix One for a copy of the email inviting participation in the survey.

Follow Up Interviews

A letter seeking formal consent was sent to all Flagship staff who indicated their willingness to participate in the follow up interview. The letter explained the purpose of the interview and included a consent form for the interview subject to sign (see Appendix Three for a copy of the letter and consent form). All consent forms were signed and returned to the Author prior to undertaking the interview.

Prior to conducting the online survey and interviews a stage two ethics approval was sought from and granted by the Australian National University Ethics Committee – protocol number 2009/020. In addition further steps were undertaken to safeguard individuals' identity. The online survey was conducted anonymously, and all interview subjects were given the opportunity to refuse to be identified in the thesis and,if they chose on reading of the final draft, for their comments to be withdrawn from the thesis.

One interview subject requested not to be quoted in the sub-thesis, resulting in the interview being analysed but not quoted in the write up. In addition two interviewees requested that they only be identified through a pseudonym in the sub-thesis. All interviews were taped, except one where permission was not given, and notes of the interviews were recorded. All recorded interviews were then transcribed and then collated into themes for analysis.

In the end during the data analysis the decision was made to anonymise all interview participants, except the participant who asked not to be quoted, for consistency and due to the increasingly political nature of knowledge transfer within CSIRO.

Sample Population

In order to better understand the processes currently used to communication information regarding climate adaptation issues, it was thought necessary to canvas as wide a variety of researchers as possible within the sample population, given that different research fields would have different ways of transferring knowledge. Therefore in order to cast the survey net widely, but with a target, all staff within CSIRO Climate Adaptation Flagship were invited. While there may be staff who work on climate adaptation issues in CSIRO but outside of the Flagship, they are rare. In addition, staff were asked to pass along the invitation, a process known as snowballing, to any CSIRO colleagues they felt had an interest in climate adaptation. In this way it was felt that all CSIRO staff working on climate adaptation issues, estimated at 150 staff, had an opportunity to respond to the survey and participate in the follow up interviews.

Eight follow up interviews were conducted with staff who had indicated their willingness to participate, and with whom interviews could be arranged in a timely manner. In order to gain a complete understanding of CSIRO researchers' thoughts on transferring knowledge on climate adaptation issues it would have been ideal to interview all members of the Climate Adaptation Flagship; however, the extent of this undertaking was beyond the scope of this sub-thesis.

A decision was made to finalise the interview process after the eighth interview in mid August 2009 after sufficient data had been collected to analyse and address the research questions. Knowing when to stop collecting data has been well discussed in the literature, with the principal idea that the research will reach a 'saturation point' where perspectives and issues begin to recur. Over half of the interviewees repeated previous ground, so a saturation point was reached in both the online survey and follow up interviews.

Data Collection, Processing and Analysis Procedures

Survey

In May 2009 an email was sent to all CSIRO Climate Adaptation Flagship staff informing them about the case study and inviting them to participate in the voluntary anonymous online survey, using the ANU polling system APOLLO. Since the survey was electronic, participants filled in their answers online and entered their answers by pressing the submit button at the end of the set of questions. Submission of the survey was viewed as their consent to participate, with a paragraph outlining the participant's rights located prior to the submit button.

Once the survey had closed reports were then run through the Apollo system to collect and collate the data. These reports were exported to either an excel spreadsheet or text file. The following three reports were run on the data:

- Poll to CSV – a report that collects all responses, and collates multiple choice and radio button answers

- Others and comments – to pick up the responses from the Other and Comments fields of the survey. This allowed for more detail to be gathered on participants' opinions.
- Textual answers – to pick up any remaining comments

These reports were then analysed using a 'pattern matching' technique as described by Campbell (1975, as cited in Tellis, 1997). Pattern matching is a process of matching information from the case study to a theoretical scheme, in this case study the issues, barriers and opportunities highlighted in the literature.

Interviews

Participants were invited to participate in the follow up interview process via the first email informing them of the case study and in the last screen, or thank you page, of the online survey. Once volunteers indicated their willingness to participate, an appointment for the interview was established via email correspondence, although in some cases staff indicated their willingness during chance encounters at the work place.

The semi-structured interviews took between 20 and 30 minutes to complete and were undertaken either face to face or via telephone (see Appendix 5 for structure). The decision to record the interview was taken to enable an accurate record to be obtained, and for clarification of the interview notes. This is consistent with research practices identified in the literature of similar case studies, such as described in Holmes and Clark (2008). Only one interview was not recorded, at the request of the participant.

All recorded MP3 files were transcribed shortly after the interviews took place; an example of the transcripts can be found in Appendix Four (all files were kept in a locked draw or on a password protected computer). The interviews were then collated by question in order to assist in analysis, with responses to each of the eight questions sorted into a table with three columns. The first column contained an identifier for the participant for referencing purposes. The second column contained the participants' response to the question, while the third column allowed for coding notes by theme. The coding themes included: barriers, cultural issues, how to build relationships, and how to improve communication practices.

By sorting and coding the text in this way, it was possible to analyse the data gathered in each interview and compare them between interviews. Once coded, the 'pattern matching' technique was applied to interview data, matching the issues, barriers and opportunities to the online survey results and knowledge gained from the literature.

Triangulation

Triangulation is a process of using 'multiple methods, data sources and researchers to enhance the validity of research findings" (Mathison, 1988). In this study multiple methods were used to gather data on knowledge transfer practices at CSIRO, including an online survey, interviews and a review of the literature.

Limitations of the research methods

There are several limitations with the above method. Firstly the sample size is restricted to those who volunteered to participate, and therefore it can not be taken as a complete picture of current practice in knowledge transfer. In addition, those who volunteered to participate could be doing so as they have an interest in the topic and therefore their responses would not reflect the full spectrum of ideas.

The second limitation is that the participants are all staff of one organisation, CSIRO, and therefore the understanding and perspectives of staff working in Australian Government departments is missing. This limitation was identified early, when the original plan had been to interview decision makers in Government departments for their perspectives on knowledge transfer; however, approval for surveying and interviewing participants in Australian Government departments could not be obtained.

This study should be regarded as a preliminary study which can be expanded in the future with CSIRO more broadly, Australian researchers more generally and relevant Australian Government staff members.

Summary

This chapter discussed the method used to gather the thoughts, practices and perceived barriers to effective knowledge transfer between CSIRO's Climate Adaptation Flagship and Australian Government departments. The decision was made to conduct a voluntary anonymous online survey followed by one-on-one semi-structured interviews with willing participants. The interview questions were based on the responses from the online survey which warranted further explanation. The interviews were recorded via audio (where permission was granted) and note taking. Audio files were transcribed as soon as possible after the interviews. The data for both the survey and interviews were coded and pattern matched by theme and number of responses. While this case study has limitations, it plays a small part in understanding the issues of knowledge transfer between CSIRO and Australian government departments. It also allows for recommendations for further communication practices.

4. Research Findings and Discussion

Introduction

This chapter explores CSIRO researchers' understandings of knowledge transfer, reporting the results of the anonymous online survey and follow up interviews described in the previous chapter. This section also discusses the similarities and differences between the barriers and opportunities identified in the literature and those identified in this case study.

The study set out to explore what might be the best way to provide useable science knowledge for decision making on complex issues such as adaptation to climate change, by asking the following questions:

1. What do CSIRO researchers think is useable knowledge for the decision maker? How does this expectation differ from the literature?
2. What are the perceived barriers to knowledge transfer from the researchers' perspective?
3. What do the researchers' perceive to be the most effective and efficient pathways for communicating useable knowledge between CSIRO and Australian Government Departments?
4. How do these differ from pathways identified in the literature?

In order to answer the above questions a comprehensive literature search was undertaken followed by an online survey of CSIRO Climate Adaptation staff, exploring researchers' thoughts on the limits, barriers and current practices within CSIRO to transfer knowledge with Australian Government departments. Semi-structured interviews followed on from the survey in order to explore some of the issues identified more extensively. While twelve staff offered to participate in the follow up interviews, in the end eight staff were interviewed due to information saturation and an inability to co-ordinate all interview opportunities given staff time constraints.

Online Survey

The online survey was open for 24 days during May 2009. During this time 31, out of a possible 150 staff, chose to participate by submitting answers to the online survey. Of the staff who responded to the survey, 29 worked with Australian Government departments on climate change related issues in the last 12 months. All respondents had a university degree, with 28 also having a higher degree, which was congruent with the majority of respondents (23) identifying themselves as researchers, while 10 identified themselves as managers, and 4 as communicators.

After reviewing the literature respondents' gender was not deemed relevant to the way researchers thought about decision making, however age was, with a majority of respondents falling between the ages of 36 and 45. Respondents had a wide array of research backgrounds, including physics, mathematics, ecology, geology, engineering, architecture, climate modelling, social and environmental science. This demonstrates the wide variety of skill sets and thinking that makes up the CSIRO Climate Adaptation Flagship, which would in part account for the variety of perceptions to how best to transfer knowledge. Further demographic details can be found in Appendix 6.

To set the scene, respondents were asked to indicate their satisfaction levels with information that they currently received from government departments, with just over half feeling dissatisfied with the information received. However satisfaction levels lowered even further to 35% when asked to consider how satisfied they were with the information that they provided government departments. During follow up interviews it was suggested that researchers' dissatisfaction stems from the highly critical nature of most scientists (Interviewee 4).

Role of Science in Decision Making

Respondents had a wide variety of thoughts when asked to give their opinion on what purpose departmental staff put science information to in decision making on climate adaptation issues. Comments ranged from an uncertainty as to how departmental staff used

science information, to very specific examples of science uptake in decision making. On the whole, just over two thirds of the suggestions were a combination of:

- Assessment of evidence to determine the likely impacts of climate change
- Facilitation of decision making and assisting in the formation of public policy and legislation
- Educating government staff and their stakeholders (Ministers, interest groups, the public etc)
- Guiding future investments of time and resources

However transparency of information use was highlighted as a concern to some respondents; one in particular suggested that "I might be more motivated if I knew how science was used. Sometimes I suspect it is just 'filed'". This, and other similar responses, lead to follow up questions on understanding the decision processes of government departments.

What makes knowledge useable for decision makers?

Respondents were asked what they viewed to be the most important characteristics of knowledge and what makes it useable for decision making. The most popular response was timeliness, followed by credibility, accuracy, plain English and impartiality (see table 1). However when the data is explored further, accuracy turned out to be the characteristic that was most often ranked top, followed by timeliness and credibility. This idea of accuracy as the most important trait is consistent with CSIRO role as a science organisation.

Table 1 – Characteristics of knowledge that CSIRO researchers believe make it useable for decision making (% of total responses relates to the number of respondents, who selected this characteristic; since more than one characteristic could be selected the table total is more than 100%).

Characteristic	# of times selected	% of total responses	Frequency of top selection
Timely	26	84%	8
Credible	24	77%	7
Accurate	21	68%	10
Provided in plain English	20	65%	2
Impartial	14	45%	0
Transparent	12	39%	1
Accountable	10	32%	0
Salient	9	29%	1
Peer review	7	23%	0
Legitimate	6	19%	0
Risk	6	19%	1
Certainty	4	13%	0
Inclusiveness	2	6%	0
Other [Relevance]	1	3%	1

Communicating knowledge

Respondents were asked to identify ways that they felt CSIRO could share information with Government Departments that would improve the Government's ability to make decisions on climate adaptation issues. Respondents had many suggestions from the general to the very specific, including improving communication practices, co-producing knowledge, relationship building, secondments and the use of knowledge brokers. However one staff member suggested that "the information is shared effectively by CSIRO, I think the questionable filters lie outside the CSIRO domain".

Conversely respondents were asked to identify ways that they thought Government Departments could share information with CSIRO that would improve the Government's ability to make decisions on climate adaptation issues. Responses included a similar set of answers to the previous question, including: knowledge brokers; formal communication

mechanisms, working in partnership and relationship building. However, there were some other interesting suggestions, including:

- Reducing churn, or the high turn over of staff in Government departments, by establishing "continuity within government departments that preserves relationships". The greater the staff turnover, the more difficult it is for researchers to develop a useful network.
- Improving access to government held information
- Involving CSIRO earlier in the decision making process, rather than using science as an "add in" later on in the processes
- Convey political imperatives and position, goals and strategy, as well as the barriers, including economic drivers and "the fear of offending voters"

Respondents were also asked who had the responsibility for making science knowledge useable for decision making. Most of the respondents (24 of the 31) felt that they were responsible for making science knowledge useable, although there was also a strong preference for science communicators and research managers to have a role. The media had the lowest score for making information useable. This is an interesting point as it is contrary to information found in the literature, which highlights that the media is increasingly looked on by the public, and decision makers, to make science understandable (Good, 2000).

Table 2 – responsibility for making science knowledge useable for decision making (% of total responses relates to the number of respondents; since more than one option can be selected the table total is more than 100%).

	# of times selected	% of total responses
Researchers	26	84%
I am responsible	24	77%
Science communicators	23	74%
Research managers	22	71%
The users of information	16	52%
Research funding bodies	13	42%
The media	10	32%
Other [knowledge brokers and consultants]	3	10%

Competing Priorities

Respondents were asked to state, other than climate adaptation science, what considerations they believed departmental staff should take into account when making decisions on climate adaptation issues. The economic down turn featured prominently in the results; this could be due, in part, to the fact it was given as an example answer. However, news of the economic down turn has dominated the media over the last year, so it is possible it was at the forefront of respondents' minds. Other considerations identified centred around three main themes; politics (including public opinion), uncertainty and competing priorities.

Politics was listed frequently in the responses, with respondents identifying the interests of various actors including the Minister, industry, lobby groups and the voting public. Internal politics and the short term cycle of local and national elections, with their associated promises, were considered to be important factors in decision making. External political drivers were also mentioned, including international politics and obligations, with respondents suggesting that other countries' climate change policy initiatives impacted on decision making in Australian government departments.

Uncertainty was identified as a consideration for decision making, including uncertainty around the climate debate, about future socio-economic conditions, the cost of adaptation,

and about stakeholder responses to policy decisions. Other areas of uncertainty included misconceptions and biases of existing views of key decision makers.

Respondents also noted that decisions needed to be made in context and be consistent with existing policies and measures. It was also noted that there were multiple and competing priorities on the governmental agenda at any one time.

Respondents were then asked a series of questions asking them to reflect on what considerations, other than climate adaptation science, they believed Government departments could take into account when making decisions on climate adaptation issues. The most frequent suggestion was the need to take a long term view of what is wanted in Australia, considering societal values, quality of life and how decisions will impact on future generations. Other considerations included the broader range of policies, such as economics, health and emergency services. Individual and businesses' capacity for adaptation, population (growth or decline), indigenous knowledge and what is happening internationally, were also mentioned. One respondent suggested that:

> "Climate adaptation ideally should be mainstreamed in all portfolios, so the reverse question might be more appropriate - every portfolio should do its normal business with its normal drivers but include climate adaptation into every consideration."

Respondents were asked to comment on whether this additional knowledge, other than climate science, made decisions on climate adaptation policy better or worse. Out of the 28 respondents who answered, 18 said it made better decisions, while 6 thought it made worse policy decisions. However, 26 respondents chose to comment on this question, with a majority of comments suggesting that this was irrelevant as "science is always only one of the streams of information used by governments to make decisions". The comments suggesting policy would be worse off with additional knowledge were more along the lines of not allowing short term considerations and goals to over ride long term needs and thinking.

Science's Influence in Decision Making

Respondents were also asked if they felt that science was involved sufficiently early in the decision making process, with 19 respondents suggesting that science wasn't involved early enough. The range of comments included questions about whether decisions were being made at all, or that science was being brought in at the last minute as 'window dressing'. However, some respondents suggested that the situation was improving due to improved communication skills of researchers and relationship building.

About 90% of respondents felt that CSIRO researchers should have influence in departmental decision making, with many respondents highlighting that that is the role of CSIRO, as formally outlined in CSIRO's charter and why it is funded by tax payers. However, some respondents felt that CSIRO researchers should not have direct involvement in governmental policy, indicating that CSIRO needs to remain impartial and play an 'honest broker' role for government. Respondents also felt that governmental decision makers should gather as much knowledge, from as many sources as possible, in order to make decisions.

Uncertainty and Knowledge Transfer

Respondents were asked to comment about uncertainty in climate adaptation knowledge, in particular whether more science was the answer to better decision making. Approximately 68% of respondents felt that more science was the answer, whereas 26% felt that it was not. Respondents' felt that it was "science's job to reduce uncertainty", but that more research was only part of the answer, indicating that more engagement was required, as "science could never be 'certain' no matter how much research is done" and that in the real world we will "always have to operate with imperfect information".

Almost 97% of respondents felt that there could be a better application of existing knowledge, with some suggesting that the current uptake of knowledge could be enhanced by improving the "accessibility of science knowledge to decision makers". There were also suggestions that researchers should have a greater awareness of the needs of decision makers, and that there could be a lot to learn from the "social science fields about

collaborative learning and adaptation to change". It was felt that this topic warranted further exploration, and therefore it formed part of the follow-up interview questions.

Asked whether research should be able to eliminate uncertainties for decision making, 87% of respondents felt it could not, some suggesting that this was an unrealistic expectation. Interestingly respondents felt that decision makers shared this view, with 20 respondents feeling that decision makers have 'some to medium tolerance' to uncertainty. Four thought there was a high tolerance, and only six felt there was little tolerance. One respondent pointed out that "politics is precisely about balancing tradeoffs and uncertainties".

This idea concurs with Tribbia and Moser's (2008) study of climate change and coastal managers, where respondents did not consider uncertainty in climate change science a significant obstacle to taking action on the issue. However Langsdale (2008) and Shackley (1996) also identified that decision makers tend to be risk averse, preferring to see a reduction in uncertainty prior to making decisions. It was decided to explore this further in the follow up interviews.

Respondents were asked how they thought government department decision makers like to be informed of uncertainties in climate adaptation science. This question produced an array of answers, from the simple "I have no idea" to the very specific "I think the IPCC method is useful" or using "visual information" to communicate knowledge. One respondent suggested that "the more uncertainty is dealt with in the media, the better". Other responses centred on the need to communicate uncertainty through face to face meetings, and in clear detail at all stages of reports, particularly up front in executive summaries. These responses are consistent with best practice identified in the literature, apart from the IPCC suggestion, which Pielke (2002) has suggested is not a useful way of communicating uncertainty to decision makers.

However some respondents felt that decision makers do not like to hear about uncertainty, indicating that uncertainty makes decisions harder, and that in some cases this can influence how uncertainty is reported. One respondent went so far as to suggest that "experts (rather than governments) are the best people to make decisions involving uncertain science". However as Lansdale (2008) notes "both scientific experts and laypersons have been found to have too much confidence in highly unreliable data".

Respondents were asked if they felt that scientific uncertainty acts as an impediment to decision making in government departments. Twenty one respondents indicated yes, while nine disagreed. This answer seems to conflict with earlier responses, suggesting that decision makers were comfortable with uncertainty. However respondents clarified their answers by suggesting that uncertainty is sometimes used as an excuse for inaction. One respondent highlighted the "plea of the Danish Prime Minister to scientists at the Copenhagen conference 'please tell us the answer now'".

Another explanation of the inconsistency was provided by another respondent who suggested that:

> "the belief that uncertainty acts as an impediment (promoted by scientists of some types sometimes), but uncertainty isn't actually an impediment to policy decision making in principle. It may impede getting the right answer the first time, but that is often less harmful than not making any decision at all."

Barriers to Knowledge Transfer

Respondents were asked to identify perceived barriers to knowledge uptake in climate adaptation issues in government departments. Competing priorities proved to be by far the most commonly selected option with 24 respondents identifying that barrier, followed by competing interest groups, cultural differences, lack of capacity and uncertainty in climate information. However, the data showed that: competing priorities, cultural differences and uncertainty in climate information were equally important first choices for participants.

Table 3 – Perceived barriers to knowledge uptake in climate adaptation issues for government departments (% of total responses relates to the number of respondents, who selected this barrier; since more than one barrier can be selected the table total is more than 100%).

Barriers	# of times selected	% of total responses	Frequency of top selection
Competing priorities	24	77%	5
Competing interest groups	16	52%	4
Cultural difference between science and decision makers	14	45%	5
Capacity for knowledge uptake	13	42%	2
Uncertainty in climate information	12	39%	5
Access to science information	9	29%	1
Difficulty in understanding the language of science/decision makers	9	29%	1
Lack of time	7	23%	1
Lack of resources	7	23%	1
Societal values	5	16%	
Lack of rewards for researchers engaged in knowledge transfer to decision makers	5	16%	
Volume of information available (too much)	5	16%	
Public awareness of the issues	3	10%	
Personal values	3	10%	
Lack of staff	2	6%	
Volume of information available (too little)	2	6%	
Other (please specify) [competing agendas, politically unpopular, relevance of information, rewards/incentives in government departments, lack of understanding the needs of policy makers, lack of understanding]	8	26%	

Governmental Knowledge Systems and Processes

Respondents were asked about their understanding of the knowledge systems and processes of government departments. Respondents were also asked to what extent they felt their

colleagues had an understanding of these knowledge systems and processes, and how important they felt it was that CSIRO staff should have an understanding of these processes. Seventeen respondents felt that they had an understanding of governmental knowledge systems and processes, while 14 felt they did not. On the question of whether they felt their colleagues had an understanding, 25 said no and only 5 indicated yes, suggesting that overall respondents felt that their colleagues did not have an understanding of governmental processes. Out of those who responded, only one felt it was somewhat unimportant to have an understanding of knowledge systems and processes of government departments, and four respondents were neutral. During follow up interviews, Interviewee 4 suggested that these results may be prejudiced as the nature of the survey would attract volunteer participants that are trying to work with government departments, and feel that CSIRO should be doing more in this space. This was also expressed in the comments section of the survey, with respondents suggesting that most staff do not engage with government departments, with a few notable exceptions. Others suggested that there was little understanding of the processes, virtually no communication on this issue, and no training in government processes and culture available for researchers.

Table 4 – CSIRO staff's perception of the importance in developing an understanding of knowledge systems and processes of Government departments

	# of times selected	% of total responses
Important	11	35%
Very important	7	23%
Somewhat important	7	23%
Neutral	4	13%
Somewhat unimportant	1	3%
Unimportant	0	0%
Of no importance	0	0%
N/A	0	0%

Respondents were then asked what they felt researchers needed to know when providing information to, or receiving information from, Government departments for decision making on climate change issues. Responses broadly fell into five areas:

- identifying the user or target audience and tailoring the information to their needs
- identify and develop relationships with those decision makers who might be the most receptive or influential
- ensuring that information is appropriate and reliable, while understanding that less is often more for decision makers
- provide options for decision making, with an understanding of the limits and uncertainties surrounding the issue
- how government decision making works, decision makers' motivations, how they engage and communicate, and how they relate to politicians

Respondents were then asked to rank suggestions on what they thought were the most effective and efficient ways to transfer information between CSIRO and Government departments for the generation of useable knowledge for decision making on climate adaptation issues. Collaboration on projects from an early stage was by far the most popular selection, followed by secondments and regular face to face meetings. However, when looking at the most popular first preference, 'collaboration on projects from an early stage', scored only marginally higher than local scenarios, face to face meetings, targeting seminars and knowledge brokers.

Comments to this question add to the debate, with some respondents suggesting that knowledge brokers are a waste of time, while others suggested that the use of knowledge brokers should be promoted, but acknowledging the "rewards for being a knowledge broker are minimal". A number of respondents also suggested that government departments needed to share their own information with researchers, "otherwise we are working blind". Others suggested knowledge could be transferred through online information and data sources and websites.

Table 5 – Suggestions on what are the most effective and efficient ways to transfer information between CSIRO and Government Departments for the generation of useable knowledge for decision making on climate adaptation issues (% of total responses relates to the number of respondents; since more than one option can be selected the table total is more than 100%).

	# of times selected	% of total responses	Frequency of top selection
Collaboration on projects from an early stage	21	68%	6
Secondments	16	52%	1
Regular face to face meetings	15	48%	4
Stakeholder participation in research projects	14	45%	3
Targeted seminars/information sessions	14	45%	4
Personal contacts	14	45%	1
Local scenarios for climate adaptation	12	39%	5
National scenarios for climate adaptation	11	35%	1
Knowledge brokers	10	32%	4
An adaptation science information website (clearance site for current knowledge)	9	29%	0
Collaboration on projects at any stage	4	13%	1
Fact sheets (available from the CSIRO website)	2	6%	0
A 'science for decision makers' journal	2	6%	0
Hands on training	2	6%	0

Follow up interviews

A small set of interviews followed the online survey in order to flesh out some of the issues identified. A series of eight questions (Appendix 5) were asked of eight researchers who volunteered to participate in the interview process. While the views of eight researchers could not be a representative sample of all Climate Adaptation Flagship researchers, these views were saturated by the 8th interview so that they may be taken to be reasonably

representative of those willing to participate. In addition, the responses clarified some of the contradictions and issues highlighted in the survey.

Better Use of Existing Knowledge

The first question asked of the interviewees centred on the use of existing knowledge in decision making. Interviewees suggested that existing knowledge could be used better in decision making; however one interviewee did suggest that this had to be tempered with the realisation that not all information was useful or relevant to decision makers (Interviewee 4). Another (Interviewee 8) suggested that the amount of available knowledge was too much for anyone to process and that decision making was bound to filter out a fair proportion along with way.

Another common response was that decision makers had a general lack of awareness about what information already exists. The suggested solutions and responsibility for this varied in the responses, with some suggesting that it was CSIRO's role and responsibility to inform decision makers about the available information and where necessary synthesize knowledge. Others suggested that CSIRO should get its own information in order but would struggle to keep abreast of what other research agencies were doing (Interviewee 1).

Other barriers highlighted included time and resource constraints, the high turn over of governmental staff, a lack of knowledge or information ownership in governmental departments, and a lack of co-ordination and communication within government departments.

Interviewees pointed out that the culture of information gathering and use was quite different in CSIRO and government departments, and that decision makers in departments do not use the literature the way researchers do. Furthermore some decision makers tended to use or target particular scientists, or 'experts', for information rather than scope out what knowledge might be available elsewhere.

It was also pointed out that governmental staff had information that was relevant to CSIRO researchers. Interviewee 4 stated "I've been sent interesting papers by my government colleagues that I haven't come across yet". Interviewee 2 also mentioned this information

gap, suggesting that "governmental staff get exposed to things that we might not have heard of and it is advantageous for us to keep our ears open and our minds open so that we can take on board the information".

Understanding of Knowledge Systems and Processes

Interviewees were asked their thoughts on scientist-stakeholder interactions, with 80% of respondents to the online survey suggesting that it was important for CSIRO staff to have an understanding of the knowledge systems and processes of the Government Departments. Survey respondents thought that they understood the knowledge systems and processes of the Government Departments, but that their colleagues did not. Interviewee 4 suggested that the "apparent paradox" could be due to the respondents self selecting, with only those who "have more knowledge and interaction with government" responding.

All but one of the interviewees felt that it was important and useful for CSIRO staff to have an understanding of the knowledge systems and processes of Government Departments; however, not all felt that they themselves had an adequate understanding. It was also suggested that it was easier to work with decision makers who understood CSIRO's processes. As pointed out by Interviewee 2, "It is very hard to help someone or something unless you know enough about what they do and how they do it to be actually able to interact in an effective way, so knowledge of those processes is vital".

The one interviewee who suggested that it was not a researcher's role to understand the decision making process suggested that it is hard to understand the decision making processes of a different organisation and that to do so "would take so much energy, time and money to achieve that it would drain all the capacity away from producing the actual knowledge" (Interviewee 8). Interviewee 8 suggested that it was far more efficient to introduce a "validity check or relevance check" for research projects.

Other interviewees suggested that secondments and relationship building were a good way of understanding the culture and practices of government departments, highlighting that very little is learnt from a book. However, secondments are time consuming and expensive.

Information seminars were another suggestion for learning about government processes; however, this idea produced a mixed response - some interviewees suggested that they were not sure how interested researchers might be in this. It is possible that this type of information session would only capture staff who were already interested and who might already have an understanding of government processes.

Added to the difficulties of understanding processes and practices, researchers often have to deal with multiple government departments, each of which has a different culture, including processes and practices, and most importantly a different way of engaging with researchers. These cultures and processes are poorly documented and while internationally there are boundary organisations that can facilitate the knowledge brokering process, interviewees suggested that there are a lack of these agencies in Australia. Interviewee 2 suggested that:

> "We should have available a body of people who know the ropes, and can operate in this environment very effectively. But in fact, for various reasons, this hasn't happened and consequently we don't have significant numbers of people able to help understand the decision environment and decision processes and work with main stream scientists".

Interviewees suggested that there was scope for improvement, and had a number of suggestions for improving practices within CSIRO, indicating that there was a role for having a group of people who can assist in knowledge transfer.

> "It is not easy, but somehow we need to be doing it better" (Interviewee 3)

Engagement Practices

Currently there is a lack of consistency across CSIRO in terms of engagement practice, with some staff having no understanding, while others have developed skills in these areas. It can be difficult to build close relationships with departments, as it takes time and energy while the landscapes change rapidly. Interviewee 4 suggested that CSIRO could assist in the development of networks and mentoring, to foster communities of practice, while Interviewee 5 suggested that more informal networks were needed.

The literature review highlighted that there is often a lack of clarity among researchers on what approach to take to successfully transfer knowledge on climate adaptation issues. This was also shown to be the case in the Climate Adaptation Flagship according to the interviewees, some of whom were unsure of the best steps or processes to take, with Interviewees 5 and 6 suggesting that it was a specialised art for which there was no specific direction or guidance. Others suggested that there should be more of an emphasis on educating decision makers in government departments, indicating that researchers expect governmental staff to know more about climate change than they have found them to have. Also as noted by Interviewee 7, "you have to work out how to communicate with them with far less information than what technical people would have been prepared to absorb".

Several interviewees mentioned that the linear method of knowledge transfer was still alive and 'well' in CSIRO, with Interviewee 2 suggesting that "the modus operandi of [some] scientists is the 'knowledge injection model', where they go along to a meeting with their knowledge right up front and they try and shove it in their [decision makers] head, and then they waltz off back to their laboratory and they think the job is done".

However all participants suggested that science needs to move away from the linear model to really get to the heart of the issues. This requires listening and questioning decision makers to help put knowledge in context, in effect helping decision makers to identify the 'real' questions that they need answers to. This process is often quite involved and can experience time constraints, which is why both researchers and decision makers need to make a conscious commitment to participating in the process. Importantly, Interviewee 7 highlighted that this was not about "changing science and engineering, we are talking about changing our communication to something that fits more the needs of policy makers".

Researchers need to understand the core business of the government department that they are dealing with, and then highlight how climate change will affect the delivery of that goal. In order to do this the researcher must discover what drivers and challenges decision makers face, and then embed their knowledge in the existing structure thereby becoming part of the solution, and not just highlighting the problems (Interviewee 4).

Other studies have suggested that scientists frequently assume that their information and knowledge is reliable and useful for decision makers without necessarily checking this

assumption against reality. Most interviewees considered that this was a fair comment, however some interviewees argued that there was a difference between reliable and useful, in that CSIRO's information was reliable; however, its usefulness might sometimes be in called into question.

> "fair enough point to make, without seeming to be arrogant I think we do place an enormous amount of faith and trust in the view and objectivity into the way that we go about doing our work" (Interviewee 5)

However, Interviewee 2 thought that most researchers "habitually over estimate the importance of science in the decision making process", suggesting that scientists also overstate the reliability, relevance and capacity for integration of the information. One reason for this is to establish continuing employment, rather than solving the issue. However Interviewee 2 also thought that an experienced policy person can identify when a researcher is doing this.

Others suggested that researchers needed to understand that giving good advice is different from giving relevant advice, and that it was possible to close that gap through communication and building relationships. On the other hand, Interviewee 4 highlighted that this can sometimes lead to 'scientific gatekeepers', where decision makers have built a relationship with a particular researcher and then use them as their 'expert' on the subject in question.

Culturally the way decision makers process and integrate knowledge for decision making is different from researchers. As Interviewee 5 pointed out:

> "the complicated bit of transferring and understanding where science and information fits in the wider world involves values. Values can be fairly complicated, none of us are comfortable with or trained in, or have any expertise and there is a variety of views."

Interviewee 4 suggested that decision makers should be taken on a journey that educates them about the issues, helping government to identify what questions they really need answers to.

"One of the lessons I've had, is that this process takes a long time, so I talk about a journey. Before people can be really effective about considering alternative adaptation options they need to understand that climate change is here for real and it is going to affect them and that they have different things that they can do and think over a period of several years about how it affects them and what they can do about it. That journey, we can help people along, but we can not short circuit it. We can't come in and run a really really good workshop and get to the end of it having the answer, they have to take time to work out what is relevant. We [and decision makers] need to accept that it is a long process."

Reward Structures

Another barrier was the lack of perceived importance of relationship building and knowledge transfer, particularly in relation to the reward drivers within CSIRO. Some interviewees suggested that the reward structures at CSIRO could be altered to facilitate this engagement process.

This question about CSIRO reward structures, in particular the importance of publications over engagement for individual promotion, generated a mixed response, although most interviewees expressed a feeling that CSIRO still needs to get the balance right. Interviewees highlighted that they understood the need for impact and engagement; however, they also worried about lowering the emphasis on publications. This was particularly true when considering individual promotions, as impact with government currently counts less than publications for individual promotions.

It was also highlighted that there were limited career paths, both within CSIRO and outside the organisation, for people who only work on engagement and impact. However as Interviewee 2 pointed out "reward systems are fundamental and they have a really strong influence on not only what people see as furthering their own opportunities but also legitimising their choices". There are different reward practices within CSIRO, with some areas focusing more on publications, and some more on engagement. Some argue that the

organisation now leans too strongly towards research publications, while others recognise it is hard to measure engagement and impact.

> "I actually see CSIRO's reward system at the moment as being not just unsupportive but actually obstructive towards some of these things, so if you have the option of spending a day with a policy person or spending a day writing a paper for Nature, there is a clear message that the paper for Nature is valued more highly in the organisation" Interviewee 2

The series of interviews highlighted that staff would like this internal conflict resolved, suggesting that CSIRO needed to find the right balance between engagement and impact, while maintaining CSIRO's science prominence, both of which are seen as fundamental to CSIRO's future. This will take time to change: however, it was pointed out that the CSIRO Sustainable Ecosystems had already "changed from multi-criteria approach to recognition and merit back to more disciplinary publication approach" in line with the rest of CSIRO, which some interviewees viewed as a backwards step in the process.

Interviewee 4 suggested that this balance could be achieved by realigning the promotion process to "reflect the contributions that an individual had made to one of those areas [publication and engagement], but not in complete absence of the other, giving some sort recognition to the annual contribution that individual has made to research and application of that research in CSIRO".

With the intention of fleshing out understanding the different cultures in research and government, interviewees were asked if CSIRO researchers understood the difference between research that is good enough for policy, as distinct from what is good enough for publication. Interviewees indicated that researchers understood the tension, but didn't always know what to do about it (Interviewee 5), also that they understood that "the world is moving and there are decisions being made very day" (Interviewee 3). However as Interviewee 8 noted:

> "publication standards are very well established, and you have to meet that standard in order to get published, the rules of the game are very clear. In terms of policy I think the rules are less clear, both in terms of our side as well as the policy makers' side. So how you get your point across is not an established

process, it might be over coffee, it might be at conference, it might be in a focus group discussion".

It was also noted that the decision makers and researchers have different cultures and therefore different criteria for knowledge and different ways to communicate. Interviewee 2 suggested that decision makers' criteria are "is this useful, is this relevant, is it legitimate information that I can use, how does it accord with other pieces of information that I am pulling together from multiple sources."

Other interviewees felt that conflicting time scales were the biggest hurdle, with information's value diminishing over time. Researchers appear to be very slow at providing information; this is partly due to the publication process, which means that a piece of research can take two to three years to appear in a journal paper. One solution for this, suggested by Interviewee 3 is to "keep decision makers in the loop as the information is being generated, not when the polished report is finished".

However Interviewee 4 expressed concern about "short circuiting the publication process", as "policy impact, but it needs to be coming from the rigour of published science". This then leads to the question of how to measure quality. Interviewee 4 expressed concern about decision makers seeking the 'wisdom' of experts, which can end up being personal opinion rather than science. Interviewee 8 also commented on this suggesting that:

> "knowledge is not produced out of facts, knowledge is produced because you're an actor in a certain social system and you have links to other actors and they influence you and influence your science, and your science is not neutral and unbiased. You are following your own agenda and making it useful to the policy maker means working with that person in order to develop something that is useful for both of us".

Uncertainty and Mismatched Timeframes

The tensions of uncertainty and timeliness were also discussed during the interviews, with most interviewees suggesting that uncertainty shouldn't be a barrier, "as human beings we make decisions under uncertainty all the time" (Interviewee 5). Several interviewees

suggested that "shoving more money at resolving uncertainty won't necessarily resolve decision makers' issues", and that researchers need to get better at communicating uncertainty in presentations and publications.

There were mixed responses about how government departments dealt with uncertainty, with Interviewee 2 suggesting that "policy makers tend not to get hung up on uncertainty the same way that scientists do". Interviewee 4 disagreed, suggesting that:

> "governments tend to not respond when there is lots of uncertainty. This is the paradox. Governments know that it is better to be proactive, but they are extremely reluctant to do that. This is because it is easy to spend money on a known problem, but when you are being proactive you don't know if there is going to be a problem and it might be money wasted."

Interviewee 4 suggested that "people still need to do stuff, so we need to find ways of helping them make decisions despite the uncertainty". Interviewee 5 suggested that to help resolve decision maker's uncertainty "nothing beats face to face". Policy decisions have to be robust to cater for uncertainty, and science can still provide good quality advice, but uncertainty will still exist in that advice.

Social Capital and Trust

Interviewees were asked about their views on social capital between researchers and decision makers. While all interviewees recognised trust and respect were vital, the current process of building trust and respect is unplanned and often ad hoc, with most social capital built through projects over long time frames. The long time frames required can create a barrier, as while most CSIRO staff tend to stay in the organisation for long periods, this is not the culture of government departments which can experience a high turnover rate. However Interviewee 7 suggested that this may not always take a long time, that:

> "by building trustful relationships between people. And that doesn't have to mean spending 15 years getting to know each other, it is something that can happen quite quickly in our culture as long as there is good open

> communication and respectful listening and the sharing of knowledge and friendly openness, and responsiveness to want to work with people in policy".

It was recognised that researchers need to commit to the participation process, which can allow for a shared understanding and then "possibly respect and familiarity between the scientists and the policy makers" will develop (Interviewee 2). Interviewee 7 expanded this idea, suggesting that:

> "building social capital and trust is about building relationships with people, people will value what you have to say because they see you listening. There is a big aspect of reciprocity in this".

It was recognised that CSIRO as an organisation still has a lot to learn about building social capital, and there is some debate about which parts of the organisation should be focused on its development. Suggestions for improving trust and respect included increased engagement activities, such as participation on projects, in meetings and events. CSIRO needs to create an organisational understanding about who are the best contacts within any government department, while trying to build networks at all levels of both CSIRO and government.

Some noted that departments had their role to play too, indicating it is possible to erode social capital as well as build it. One respondents highlighted that it is "hard to work with government departments when you feel you have been let down by a rapid change in priorities or a very fast moving process, but CSIRO has to maintain a productive relationship" (Interviewee 3).

Interviewees recognised that if researchers listen to decision makers, and try and create as many opportunities as possible for interaction with government, it is possible to create social capital that is worth the high transaction cost.

Summary

The survey and follow up interviews demonstrated that CSIRO researchers are aware of what makes knowledge useable for decision makers and feel responsible for making

knowledge useable. This chapter also outlined the perceived barriers and other issues CSIRO researchers associate with knowledge transfer. It highlighted the pathways in which CSIRO researchers practice to improve knowledge transfer and effective information uptake in government departments.

The following chapter uses these insights to answer the research questions, draw conclusions, and suggest possible pathways forward for better CSIRO knowledge transfer practices.

5. Conclusion

Introduction

This sub-thesis set out to explore how selected CSIRO researchers transfer useable knowledge to decision makers in Australian government departments, the barriers they face and opportunities for improvement in communication practices. To do this the study explored the literature to determine what makes knowledge useable for decision makers, and how this understanding differs from the expectations of researchers. The literature review also delved into the barriers to knowledge uptake, including the issue of uncertainty, knowledge and information gaps, and the inherent cultural differences between research organisations and government departments.

The previous chapter outlined a case study exploring CSIRO researchers' views on knowledge transfer practices as compared to those identified in the literature review. A voluntary anonymous online survey, followed by eight one on one interviews provided the data for the case study. This study compared CSIRO staff perceptions with insights and techniques identified in the literature, in order to explore what might be the best way to provide useable science knowledge for decision making, on complex issues such as adaptation to climate change. This dilemma was delved into by asking the following questions:

1. What do CSIRO researchers think is useable knowledge for the decision maker? How does this expectation differ from the literature?
2. What are the perceived barriers to knowledge transfer from the researchers' perspective?
3. What do the researchers' perceive to be the most effective and efficient pathways for communicating useable knowledge between CSIRO and Australian Government Departments?
4. How do these differ from pathways identified in the literature?

This chapter explores the insights gained from the case study and literature review in light of the research questions and provides suggestions for improving knowledge transfer practices within CSIRO's Climate Adaptation Flagship.

Science's role in decision making

Science is increasingly called on to provide knowledge for decision making; this is particularly true in the complex areas of climate change and climate adaptation. Around the world sound science advice is a key input to policy formulation, with decision makers calling for the production and diffusion of more useful information. In Australia the government sees CSIRO as a resource to help answer their questions and inform decision making.

Climate change is a global issue, with researchers around the world struggling with how best to provide information to users, recognising that more information does not necessarily lead to answers for decision making. Nor does communicating research findings necessarily mean that the knowledge has reached its target audience or been understood.

As would be expected in a highly diverse research organisation, there was a plethora of views as to the role of science in decision making. These views covered the role of the researcher as a source of knowledge, the value of science in decision making and the mismatch in time frames between science and policy. As highlighted in the literature review, Pielke (2007) outlined four roles for researchers, Pure Scientist, Science Arbiter, Issue Advocate and Honest Broker. CSIRO staff, through the survey and interviews, identified themselves with all roles, with little consensus of which role or roles CSIRO staff ought to fill. However as Pielke (2007) mentioned there is a place for all the role types in a functioning democracy, outlining that a researcher needs to be clear which role he or she is performing. This is an area for CSIRO leadership to provide guidance on the expected role(s) of staff. At the current time there is a lack of clarity amongst staff as to which role to play.

Useable knowledge

CSIRO researchers demonstrated that they are aware of what makes knowledge useable for decision makers, and that they see the importance in creating knowledge that is useable. Throughout both the online survey and interviews, researchers told a very similar story to the useable knowledge insights identified in the literature. CSIRO researchers recognised that relevancy, timeliness, credibility, accuracy, and impartiality, as well as communicating in plain English, were all important criteria of useable knowledge.

CSIRO researchers also acknowledged that they needed to work on improving their communication practices, and that some of the best ways of transferring knowledge came through the co-production of knowledge, developing scenarios, building relationships and undertaking secondments with government departments. Researchers highlighted the role of knowledge brokers or boundary spanning individuals; however, there was a feeling that this role was not encouraged within CSIRO's reward structures, and that these roles were under developed in Australia. CSIRO should consider exploring the engagement issue further, through realigning its internal practices, and by growing its capability for engagement with stakeholders.

These suggestions are not inconsistent with the useable knowledge and engagement literature. The results suggest that some CSIRO researchers find it easier to focus on what they are good at, namely providing reliable and accurate information, rather than focusing on engagement and ensuring the information relevance to decision makers. This is consistent with the traditional training of scientists, where the PhD process focuses on accuracy and reliability, and not on communication or engagement with non scientific users of knowledge.

While this was not the same with all case study participants; some showed a strong inclination for engagement and impact through informing decision making. This made it clear that CSIRO accommodates many individuals with conflicting perceptions and expectations of their research and role within the wider community; suggesting a need for clearer organisational understanding of the role of researchers within CSIRO. Participants highlighted that there was virtually no communication on this issue, and no training in government processes and culture available for researchers. As Interviewee 5 pointed out:

> "the complicated bit of transferring and understanding where science and information fits in the wider world involves values. Values can be fairly complicated, none of us are comfortable with or trained in, or have any expertise and there is a variety of views."

An interesting difference between the literature and the case study was the perception of the role of the media in transferring knowledge. CSIRO participants suggested that the media was the least responsible for making information useable, while the literature suggested that the general public, and decision makers, rely on the media to inform them of the issues (Maxim and van der Sluijs, 2007).

CSIRO already has a well developed communication plan, and each Flagship has multiple dedicated communicators; however researchers recognised their own lack of skills in communication for both dealing with the media and decision makers. Interviewee 7 suggested that CSIRO researchers should be "changing our communication to something that fits more the needs of policy makers". CSIRO currently provides training for publications and dealing with the media; however, there is currently little training provided for general communication skills and engagement practices with stakeholders and decision makers. This is an area that CSIRO should explore further.

Perceived barriers to knowledge transfer

CSIRO researchers identified similar barriers to knowledge transfer as those highlighted in the literature, including competing priorities and interest groups, lack of resources, scientific uncertainty and the culture gap between researchers and decision makers. Researchers felt that government also has a role in breaking down the barriers and making knowledge useful.

Researchers identified the major barriers to be competing priorities, cultural difference and uncertainty in climate information. Since CSIRO has no control regarding the competing priorities of decision makers, it can only keep them in mind when thinking about how to address the questions. As spelt out by Interviewee 4 "I think it is really important to try and find out from government what their core business is or what they are trying to do in the

absence of climate change and then help them explore how climate change affects the delivery of that goal".

Where CSIRO can have an impact is on the issues around uncertainty and cultural differences. As pointed out by Interviewee 2, "It is very hard to help someone or something unless you know enough about what they do and how they do it to be actually able to interact in an effective way, so knowledge of those processes is vital". Therefore it is important that CSIRO assists its staff to gain a better understanding of the knowledge systems and processes of their stakeholder audience(s), through improving listening and communication skills.

Reward Structures

CSIRO's current reward structure has competing priorities between publications and engagement activities, with some staff feeling that it is "not just unsupportive but actually obstructive" to the process of engagement with decision makers (Interviewee 2). Pielke (2007) suggested that "a better approach would be to create institutional processes that facilitate the connections of science with policy-making, rather than trying to somehow keep them separate" (p.149). CSIRO should therefore review its reward structures to see if there really is a barrier to achieving organisational engagement objectives, and determine if it has the 'right balance' between publication and engagement.

Pathways for communicating useable knowledge

Participants had a wide variety of thoughts as to decision makers' views of scientific uncertainty and how it impacted on decision making. Some thought that decision makers are stifled by uncertainty, while other thought that decision makers were relatively comfortable with making decisions under uncertainty. Both views were also expressed in the literature. Not all participants were sure of the most appropriate way to communicate uncertainty to decision makers, although all recognised how important the issue was to communicate. Interviewees expressed a strong preference for working through uncertainty

with decision makers, suggesting that by communicating effectively and building trust it was possible to remove uncertainty as a barrier to knowledge transfer.

Participants also highlighted the culture gap between CSIRO and Australian Government departments, with many comments about the resource constraints within both entities, conflicting reward structures and the lack of science understanding within government departments. Suggestions for resolving this included the creation of communities of practice to assist researchers in understanding and working with government decision makers. Others also suggested that science should be "mainstreamed into all portfolios". As outlined in the literature review, the Canadian government has started to implement a mainstreaming science approach (Keough, 2002). This is potentially a suggestion that senior CSIRO leaders could suggest to the heads of Australian Government departments.

Some staff expressed uncertainty about how best to engage or work with decision makers. CSIRO have several options to help fill this gap: it could develop communities of practice centred around particular government departments or stakeholder group. It could develop a mentoring program, with senior staff who are well versed in engaging with decision makers working with less experienced staff to teach them the ropes. CSIRO could also look at running workshops or training sessions on stakeholder relationship skills for impact, and improving general communication practices.

Limitations

This case study has looked at CSIRO Climate Adaptation perceptions and practices, and therefore generalisations are limited. In addition the case study has only explored one side of the knowledge transfer process and therefore may not paint a balanced or fair portrait of the system as a whole. While all knowledge transfer processes are different, this case study is comparable to similar case studies undertaken elsewhere in the world and can therefore provide some insights into the science/decision maker interface in Australia.

Suggestions for further research

This case study explored the perceptions of a small, but diverse, group within CSIRO. A more informed understanding of organisation wide perspectives would be an advantage for setting institutional objectives for knowledge transfer. Therefore a case study of the whole of CSIRO would be advantageous to explore the breadth of perceptions in order to implement an education and impact strategy.

In addition, research into the perspectives of decision makers in Australia Government departments would provide a more holistic picture of the knowledge transfer process. This would provide researchers with a much needed way of receiving feedback on their communication practices, and would hopefully allow for greater understanding and improved knowledge transfer practices between decision makers and researchers.

Recommendations for CSIRO Climate Adaptation Flagship

This sub thesis has highlighted five opportunities for staff of the Climate Adaptation Flagship to improve their ability to communicate useable knowledge to decision makers.

1. **Clarify staff roles and expectations**
   The case study highlighted that there is a lack of clarity about CSIRO's role in decision making and providing science knowledge to government. This lack of clarity was particularly evident when the reward structures were discussed, with some staff suggesting that how to balance the competing priorities of publication and engagement was unclear to them.
2. **Implement decision maker engagement plans**
   While staff were not always clear about their role, they were quite clear about what made knowledge useful to decision making, with their suggestions consistent with best practice identified in the literature. Most staff were also aware of possible approaches to take to engage with decision makers. The gap seemed to be putting that knowledge into practice. To close the gap, the Climate Adaptation Flagship Leadership Team should implement decision maker engagement plans and then assist staff in realising them.

3. **Train staff in communication skills, in particular how to engage effectively with decision makers**

   Some staff expressed uncertainty about how best to engage or work with decision makers. While CSIRO currently provides training for publications and dealing with the media, there is currently little training provided for general communication skills and engagement practices. CSIRO have several options to help fill this gap. It could develop communities of practice centred around particular government departments or stakeholder groups. It could develop a mentoring program, with senior CSIRO staff, and possibly Australian Governmental staff, who are well versed in engaging with decision makers working with less experienced staff to teach them the ropes. It could also look at running workshops or training sessions on stakeholder relationship skills for impact, and how to communicate with non scientific audiences.

4. **Reward staff for successful engagement with decision makers**

   The Climate Adaptation Flagship could set up a transparent reward system to encourage good engagement practice among research staff and teams, which would be run in parallel to the current organisational annual performance review. This would complement rather than compete with existing reward structures within CSIRO, and allow for the Climate Adaptation Flagship to find the 'right balance' between publication and engagement.

5. **Develop a network of CSIRO boundary individuals or knowledge brokers**

   CSIRO and the Climate Adaptation Flagship already has people undertaking the role of boundary individuals or knowledge brokers with demonstrated success with government departments. However, these individuals are few and far between, and often face a lack of career development or acknowledgement. Since CSIRO is a science organisation it would be appropriate that these boundary individuals are researchers. To grow the skill sets within CSIRO it would be good if the organisation encouraged senior researchers, who have a history of successfully engaging with stakeholders, to run mentoring programs for staff. Alternatively CSIRO could encourage senior staff to take a sabbatical from science for one to two

years to engage with key governmental decision makers, and assist research teams to communicate their knowledge.

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Appendices

Appendix One – Email requesting participation in online survey

Dear colleague,

Have you ever wondered if there was a way of having more impact with your research? Have you ever questioned what might be the most effective way to communicate with stakeholders? For my Masters sub thesis I am exploring optimal ways to provide the Australian Government, through it's many departments, with useable knowledge for decision making on climate adaptation issues.

Please take the time to complete this online survey (approximate completion time is 15 minutes). Please pass on this survey to CSIRO colleagues who also work on climate change and climate adaptation issues. You can do this by forwarding this email, or alternatively direct them to the following link https://apollo.anu.edu.au/default.asp?pid=3730. This survey is anonymous and all responses will be kept confidential. While I hope that you will want to complete the online survey, by keeping the survey anonymous, I will have no way of knowing if you have or have not completed the survey.

Following this anonymous survey I will be conducting follow up interviews with willing participants. These interviews will run approximately 30 minutes and will be conducted over the telephone or face to face depending on the preference of the participant. The intention of these interviews is to explore the results of the survey; your input would be greatly valued. To indicate your willingness to participate in the interviews following on from this survey please email me on seona.meharg@csiro.au. At all times your survey responses will remain anonymous, I will not be able to connect your emails with the information recorded in the online survey.

The results of the survey and subsequent interviews will be used in my sub thesis and may also be used in subsequent journal papers.

I would be very grateful if you took the time to fill in the survey. It is my hope that the outcome of this research will inform and add value to our ability to transfer knowledge to decision makers.

Regards,
Seona Meharg

Contact details:
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If there are any concerns about this project please contact:
The Human Research Ethics Committee
C/- Ms Yolanda Shave
Human Ethics Manager
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The Australian National University
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Appendix Two – Online Survey Questions

1. In the last 12 months have you worked with Government Department(s) on climate change related work? Please circle your response.

   Yes No

2. On a scale of 1 to 7, how satisfied are you with the information you currently receive from Government Department(s)? Please circle one below.

Very Satisfied			Neutral		Very unsatisfied		Unsure
1	2	3	4	5	6	7	

3. On a scale of 1 to 7, how satisfied are you with how Government Department(s) use the climate science information you provide? Please circle one below.

Very Satisfied			Neutral		Very unsatisfied		Unsure
1	2	3	4	5	6	7	

4. For what purpose(s) do you think Government Department(s) staff use science information in decision making on climate adaptation issues?

What do decision makers need?

5. Below are some characteristics of knowledge that make it useable for decision making. Please rank your top 5 characteristics according to what you believe government departments need. See boxes below; start with 1 = your most important characteristic.

Characteristic	
Timely	
Legitimate	
Salient	
Accurate	
Provided in plain English	
Credible	
Accountable	
Transparent	
Impartial	
Inclusiveness	
Certainty	
Risk	
Peer review	
Other (Please specify)	

6. Please identify ways that you think CSIRO could share information with Government Department(s) that would improve the Government's ability to make decisions on climate adaptation issues.

7. Please identify ways that you think Government Department(s) could share information with CSIRO that would improve the Government's ability to make decisions on climate adaptation issues.

8. Who has responsibility for making science knowledge useable for decision making? (Please tick as many responses that you feel are appropriate).

	I am responsible
	Researchers
	Science communicators
	Research funding bodies
	The media
	The users of the information
	Research managers
	Other (please specify)

9. Recognising that decisions are not made in a vacuum, other than climate science, what other considerations do you think Government Department(s) take into account when making decisions on climate adaptation issues? For example, the current economic downturn.

10. Other than climate science, what other considerations do you think Government Department(s) should take into account when making decisions on climate adaptation issues? For example, the current economic downturn.

11. What types of knowledge do you think might contribute the Government's decision making on climate adaptation issues?

12. What type of knowledge do you think should contribute to the Government's decision making on climate adaptation issues?

13. If you think that Government Department(s) take knowledge other than climate science into consideration when making decisions on climate adaptation issues, do you think that this makes policy better or worse?

Better	Worse	N/A

Please explain your response

14. Do you feel that science is involved sufficiently early in decision making processes on climate adaptation issues?

Yes No

Please explain

15. Do you think CSIRO scientists should have influence in decision making in Government Department(s)?

Yes No

Please explain your views

16. There are many uncertainties in climate adaptation knowledge. Broadly these can be broken down into uncertainty about models/tools, uncertainty about information/ignorance or uncertainty about the unknown unknowns. Do you think more science is the answer? Please circle your response.

Yes No

Please explain

17. Do you feel that there could be better application of existing science knowledge on climate change issues?

Yes No

Please explain

18. Should science / research be able to eliminate uncertainties for decision making?

Yes No

Please explain

19. What do you feel is the level of uncertainty in research knowledge that would be tolerated when making decisions in Government Department(s)?

No tolerance to uncertainty					High tolerance to uncertainty

20. What do you feel is the level of uncertainty in knowledge provided by CSIRO on climate change issues?

High uncertainty					Low uncertainty

21. How do you think Government Department(s) like to be informed of uncertainties in climate adaptation science? For example, statements at the start of reports, face to face discussions of the issues etc

22. Do you think scientific uncertainty acts as an impediment to decision making in Government Department(s)?

Yes No

Please explain

23. What do you perceive to be the barriers in Government Department(s) to knowledge uptake for climate adaptation decisions? Please rank the 5 barriers that most hinder your work . See boxes below; start with 1 = your most important barrier.

Barriers	
Uncertainty in climate information	
Access to science information	

Cultural difference between science and decision makers	
Public awareness of the issues	
Competing interest groups	
Capacity for knowledge uptake	
Lack of Time	
Competing priorities	
Lack of resources	
Lack of staff	
Difficulty in understanding the language of science/decision makers	
Personal Values	
Societal Values	
Lack of rewards for researchers engaged in knowledge transfer to decision makers	
Volume of available information (too much)	
Volume of available information (too little)	
Others (please specify)	

24. Do you feel that you have an understanding of the knowledge systems and processes of Government Department(s)?

    Yes No

25. Do you feel that generally CSIRO staff have an understanding of knowledge systems and processes of Government Department(s)?

    Yes No

    If no, what is inadequate?

26. How important do you think it is that CSIRO staff have an understanding of knowledge systems and processes of Government Department(s)?

Very important			Neutral			Very unimportant		N
1	2	3	4	5	6	7		8

27. What do you feel people need to know when providing information to or receiving information from Government Department(s) for decision making on climate change issues?

28. What in your opinion would be the most effective and efficient way to transfer information between CSIRO and Government Department(s) for the generation of useable knowledge for decision making on climate adaptation issues? Please rank the following ideas in their importance to you. Please rank your top 5 in the list below.

Ideas	
National Scenarios for Climate Adaptation	
Local Scenarios for Climate Adaptation	
Knowledge Brokers	
Collaboration on projects from an early stage	
Collaboration on the project at any stage	
Stakeholder participation in research projects	
Fact Sheets (available from the CSIRO website)	
Adaptation Science Information website (clearance site for current knowledge)	
A "science for decision makers" journal	
Regular face to face meetings	
Targeted seminars/information sessions	
Personal contacts	

Hands on training	
Secondments	

29. Please list ways in which you feel that CSIRO could share information with Government Department(s) that are not included on the table in Question 28?

Demographic Information

30. What is the highest education qualification you have achieved? (please tick one box)

	Year 12 Certificate (or equivalent)
	Associate or undergraduate diploma
	Bachelor's degree
	Higher Degree
	Other, please specify in the box below

31. If you have a university degree, in what field is your most relevant degree for your current role?

32. Please indicate your age (please tick one box)

	<19
	20-25
	26-35
	36-45
	46-55
	55+

33. Please indicate your role within CSIRO (please tick as many of the roles as you feel apply to you)

	Administrator
	Communicator
	Manager
	Researcher
	Other, please specify in the box below

Thank you for taking the time to complete this survey. Please pass the following link on to CSIRO colleagues who you feel would be interested in participating in this survey.

Please email me at Seona.Meharg@gmail.com if you would like an electronic copy of the thesis once it has been accepted.

To provide further input into improving the knowledge transfer between Government Department(s) and CSIRO please sign up to participate in an interview following on from this survey by emailing me at seona.meharg@csiro.au.

Please note, in keeping the survey anonymous I will have no way of knowing if you have or have not completed the survey.

Appendix Three – Consent to be Interviewed form

Consent to be interviewed and use of interviewed material

Copy to be returned to Seona Meharg

As part of a sub-thesis case study on knowledge transfer between CSIRO and Australian Government departments, I consent to be interviewed by Seona Meharg from the Centre for the Public Awareness of Science, the Australian National University. I note that participation in the project is voluntary and that I may withdraw at any time. I note that I will be given an opportunity to comment on the interpretation of material from the interview in the final draft of Ms Meharg's sub-thesis.

I also agree to (please answer yes or no):

The interview being recorded on audio tape.....

The interview being recorded by the taking of notes.....

Being quoted and identified in the sub-thesis.....

Or

Being quoted through a pseudonym only in the sub-thesis .....

Being quoted and identified in subsequent journal papers resulting from the research.....

Or

Being quoted through a pseudonym only in subsequent journal papers resulting from the research .....

Any other restrictions.....

Please note that all interview material will be stored in a locked filing cabinet for the duration of the study.

Signed:..... Date:.....

Contact details:
Seona Meharg
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If there are any concerns about this project please contact:
The Human Research Ethics Committee
C/- Ms Yolanda Shave
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Appendix Four –Interview Transcript

Interviewee 1 – Interview conducted on xxxx

1. The online survey respondents suggested that we could be using existing knowledge better in decision making. Do you agree with this statement and if so could you share your thoughts on this matter?
   - I would agree with that statement
   - So I think one of the challenges for decision makers is how they keep abreast of the science that is happening and actually understand the significance and relevance from the science, which may not have been very well described in the reports or papers
   - People who use different websites that act as a clearing house for research, but I suspect that there are a lot of things going missing simply because people don't have the time or know where to look to find out about that work
   - I think CSIRO has a couple of roles. One is to sort out our own [research], get our own house in order so to speak. There some examples I have seem recently through the climate flagship, MSS – short sharp pieces that sort of aggregated our research and really explained them, the application and the "so what" question about that work and actually use that as a sort of window in to the mush more detailed and complex research that is happening in the organisation

2. Gaining insight into how decisions are made can be considered an important part of scientist-stakeholder interactions. Approximately 55% of survey respondents felt that they had an understanding of the knowledge systems and processes of the Government Departments, 80% indicating that this was important information to know, however 80% of respondents felt that their colleagues did not have adequate knowledge. Should CSIRO researchers know how government decision making is undertaken and if so how should we learn this?
   - I think we should

- I think one of the key characteristics of decision making is that it can be quite rapid in many respects and so for CSIRO scientists it is around how you get close enough to people making those decisions to see what is happening, so that you can get a good understanding of that process
- Whether that is through secondments or other ways, I think it needs to be through some form of relationship that is stronger than a conversation at a workshop
- It can be difficult when you are trying to build that close relationship with a particular department, it takes time and it is not always successful for everyone in the team, it may be one or two people in the team that get that closer understanding
- It is not easy, but somehow we need to be doing it better

3. Often there is a lack of clarity among researchers on what approach to take to successfully transfer knowledge on climate adaptation issues. What strategies would you suggest that CSIRO researchers employ with Government Departments to effectively transfer knowledge on climate adaptation issues?
   - I think it is really getting to understanding the questions that are being asked, or the questions that government departments need answers to
   - Without the understanding of what is really at the heart of the issue or the key gaps that people are trying to understand, it is very difficult to link research, whether that be climate adaptation research or other research to the real interests that that department has
   - So I think having that understanding of what the drivers are for the department, what are the challenges they are trying to face, what are the questions that they would like to answer but can't. that is a prerequisite for us to bring our research in to address those issues

4. The literature suggests that scientists frequently assume that their information and knowledge is reliable and useful without necessarily checking this assumption against reality. Do you feel this is the case at CSIRO? How do you check to see if your information is useful?

- I think this assumption about whether the information is reliable is quite a common assumption, and is probably reasonably accurate
- Where the assumption falls down is that question of usefulness and I think it is the case that in csiro there are real gaps between the conclusions generated by the CSIRO scientists and the connection to the original question
- To be able close that gap through communication and building that relationship with the government department to be sure that the question that they are really trying to answer is addressed in the work rather than summarising the findings from the research and not being able to draw the connection to the key issue that was at the heart of the conversation originally

5. Should the individual rewards system within CSIRO have more of a focus on engagement and impact rather than on publications?
   - I think you see differences in different parts of the organisation so I see CSE as being reasonable balanced. I can think of areas that have a stronger focus on publications than us, and I can think of areas that have less of a focus on publications than us
   - But I think for CSIRO we need to find that balance because if we under recognise engagement then that is a path we don't want to go down. But if we under recognise science achievements, that is another path we don't want to go down. It's a tension that is going to continue to exist and I suspect it is not a case for further recognition of engagement its more a case of being sure we've got that balance right, and maybe that balance is found in different individuals and the expectations about promotion can reflect the contributions that an individual had made to one of those areas, but not in complete absence of the other, but giving some sort recognition to the annual contribution that individual has made to research and application of that research in CSIRO

6. In addressing the policy pressures of certainty and timeliness, do you feel that CSIRO researchers need to develop an understanding of the difference between what is good enough for policy as distinct from what is good enough for publication?

- Yes
- The world is moving and there are decisions being made very day
- If you have a string relationship with an agency and they are part of the thought process and the development of the research as it progresses. Then they can be benefiting from that science as the project goes along. As apposed to a model where csiro doesn't say anything until the final report finished and a whole lot of effort goes in to all the I's are dotted and t's crossed in that final report. Where in actual fact we have missed that key decision processes or the key opportunity to influence the outcome on the ground
- We need to be much more flexible in our understanding of provision of science to decision makers and it's a relationship rather than a report

7. Survey respondents indicated that they feel that uncertainty is not a barrier to decision making, suggesting that collaboration, secondments and meetings were the most efficient and effective way to transfer information between CSIRO and Government departments. Do you agree with this?
   - I think meetings and workshops to talk about the research, the knowns and the unknowns, can we quantify the uncertainty what that might be
   - I think using that approach should therefore not be a barrier, using that approach providing a context to people who are in a decision making role and under time frames to make decisions
   - My sense is that you can continue to provide good quality science that recognises uncertainty but uncertainty will still exist in that advice

8. How does CSIRO develop and maintain "social capital", including mutual trust and respect, between scientists and decision makers? How should CSIRO develop and maintain such social capital?
   - It is really difficult, part of it is around the people in some of the government agencies. To what extent are we able to maintain that relationship with the level of turn over in their organisation, with the level of turn over in our organisation
   - Where is the trust being built up, where is it being eroded

- I can think of examples where I have felt let down by people in departments because we thought we had some understanding about a particular set of activities and that had clearly changed. But at the same time there is a need for CSIRO to be able to continue to work closely with that organisation and continue to have a very productive relationship with that organisation.
- It is a case of being about to continue the contact
- Hopefully the successful project delivery, which includes the successful communication of the relevance of the science and that science can inform the decision making processes starts to build a mutual platform of respect for the work and the pressures that the agency might be under, and you hope that those people stay in those roles so you can continue to build that relationship
- It becomes a question of trying to secure more senior people that may last longer than some of the people in more junior, project based activities, where we might build a really good relationship based on a project but they are not able to have the influence in their organisation to promote the relationship with CSIRO and the importance of maintaining that over time

Extra Comments

I think we are increasingly being seen by government agencies as a source of knowledge, a resource to help them answer some of the big questions facing Australia and we will be continually let down if we are unable to link science effectively to the questions that need to be answered.

And we will continue to be let down if we don't have that understanding, or we feel offended when we do figure it out and the decision making process doesn't align with time frame for what we thought the science should be delivered against.

Appendix Five – Follow Up Interview Questions

1. The online survey respondents suggested that we could be using existing knowledge better in decision making. Do you agree with this statement and if so could you share your thoughts on this matter?
2. Gaining insight into how decisions are made can be considered an important part of scientist-stakeholder interactions. Approximately 55% of survey respondents felt that they had an understanding of the knowledge systems and processes of the Government Departments, 80% indicating that this was important information to know, however 80% of respondents felt that their colleagues did not have adequate knowledge. Should CSIRO researchers know how government decision making is undertaken and if so how should we learn this?
3. Often there is a lack of clarity among researchers on what approach to take to successfully transfer knowledge on climate adaptation issues. What strategies would you suggest that CSIRO researchers employ with Government Departments to effectively transfer knowledge on climate adaptation issues?
4. The literature suggests that scientists frequently assume that their information and knowledge is reliable and useful without necessarily checking this assumption against reality. Do you feel this is the case at CSIRO? How do you check to see if your information is useful?
5. Should the individual rewards system within CSIRO have more of a focus on engagement and impact rather than on publications?
6. In addressing the policy pressures of certainty and timeliness, do you feel that CSIRO researchers need to develop an understanding of the difference between what is good enough for policy as distinct from what is good enough for publication?
7. Survey respondents indicated that they feel that uncertainty is not a barrier to decision making, suggesting that collaboration, secondments and meetings were the most efficient and effective way to transfer information between CSIRO and Government departments. Do you agree with this?

8. How does CSIRO develop and maintain "social capital", including mutual trust and respect, between scientists and decision makers? How should CSIRO develop and maintain such social capital?

Appendix Six – Online Survey Demographics

All 31 respondents to the survey had a university degree, with 28 also having a higher degree. Respondents had a wide array of research backgrounds, including physics, mathematics, ecology, geology, engineering, architecture, climate modelling, social and environmental science. This highlights the wide variety of skill sets and thinking that makes up the CSIRO Climate Adaptation Flagship, which would in part account for the variety of perceptions to how best to transfer knowledge.

Table 6 – Education levels of respondents

Year 12 Certificate (or equivalent)	0	0.00%
Associate or undergraduate diploma	0	0.00%
Bachelor's degree	3	9.68%
Higher degree	25	80.65%
Other (please specify) [PhD]	3	9.68%

Respondents' gender was not deemed relevant to the way respondents thought about decision making. However age was considered relevant due to the changing nature of the science / decision maker interface over time, moving from the 'loading dock' approach to science, to a more integrated participatory model. The majority of respondents fell between the ages 36 to 45.

Table 7 – Age of respondents

<19	0	0.00%
20-25	0	0.00%
26-35	6	19.35%
36-45	11	35.48%
46-55	9	29.03%
55+	5	16.13%

Respondents where also asked to indicate their role, or roles within CSIRO. 23 respondents identified themselves as researchers, 10 as managers and 4 as communicators.

Table 8 – Role of respondents

Administrator	0	0.00%
Communicator	4	12.90%
Manager	10	32.26%
Researcher	23	74.19%
Other (please specify) [support scientist, part time knowledge broker]	2	6.45%