6

Improving science uptake in coastal zone management: principles for science engagement and their application in south-eastern Tasmania

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INTRODUCTION

Sustainable management of the coastal zone represents a considerable challenge to Australian society. This challenge is rooted in the complexity of the biophysical and sociocultural characteristics of coastal areas, including uncertainty about system characteristics and processes, and the diversity of stakeholders, their interests, values and perspectives, and the jurisdictions involved in coastal governance and management. Given this complexity of coastal zone management, scientific and other forms of knowledge can affect decision-making and human action in diverse ways, which will often depend on the ability of scientists to engage effectively with relevant stakeholders.

In this chapter we describe a series of principles that we believe underpin the successful engagement and thus application of science in Australian coastal zone management. We suggest how these might be applied to a major science initiative for monitoring and modelling coastal processes, not through prescribing particular processes or engagement strategies but through reflection on what the principles might imply in the specific contexts in which the initiative engages with stakeholders and decision-makers.

In suggesting that the contribution of science to coastal zone management can be improved, we draw on insights generated from diverse social research on the interactions between science, policy and practice. Specifically we highlight key findings from science and technology studies (STS), science and technology policy (STP) and agricultural extension. Over recent years, these disciplines have investigated various aspects of the contribution of science to environmental matters, including: the creation and resolution of public controversies; the role of science, scientists and other actors in such processes; the interactions between scientists and policy-makers in policy-making; and the reasons for non-adoption of innovations and scientific information among lay actors. This body of scholarship has rarely focused on coastal zone management specifically, yet it has provided useful critiques of how science is applied in broad issues of environmental management. Thus, we suggest, it has bearing on the issues faced in managing complex issues involving a nexus (and sometimes a collision) of technical questions, diverse private interests and political commitments, and different value and knowledge systems.

There is a variety of legitimate concerns that differ across boundaries between decision-makers, scientists and lay publics; these may not always be obvious across such boundaries. For instance, scientists may ask research questions that they can credibly answer using currently accepted methods, yet these questions (and answers) are often narrowly focused and may be of little relevance to the decisions faced by public or private sector managers. Lay people might interpret the narrow, necessarily reductionist, focus of scientific question as indicative that scientists are politically aligned. Despite such concerns, public sector managers or politicians might try to maintain that a particular issue is fundamentally a technical or scientific question, and thus imply that values and beliefs are not a central concern for decision-making. By defining an issue as technical, policy-makers or politicians can distance themselves from responsibility, pledging to be listening to (or waiting for) 'the facts'. Yet facts are rarely, if ever, truly factual. Uncertainty and scepticism are mainstays of scientific investigation, while proof, truth and fact – the staples of political rhetoric – are rarely to be found in empirical science, especially science that relates to complex systems such as coastal processes. Instead, hypotheses are tested, models built and, if evidence does not pull these apart, they become the basis of more stable knowledge and eventually consensus, perhaps even theories or laws, but never 'facts' (Oreskes 2004).

Though this is a crude sketch of how scientific knowledge sits uncomfortably in public debate, it is a familiar feature of numerous cases around the world. In some instances the way scientific knowledge is positioned in public debates, and the pretence among scientists and politicians that science might be able provide definitive answers to complex problems, has resulted in a 'crisis of legitimacy' for science (Wynne 1992). Public trust in some scientific institutions has been eroded. In some cases scientist have implicitly or explicitly become advocates for particular policy options, and thus moved much closer to politics than other scientists think is appropriate. In other cases scientists have been coerced not to engage in debates even where their research has direct bearing on the appropriateness of particular policy options. Diverse case studies that highlight how such processes have occurred, their outcomes and the theoretical insights that stemmed from them provide substantial insights into the problems facing science for coastal zone management and coastal adaptation to climate change and the need for particular forms of engagement between the spheres of science, policy and practice.

This chapter has three sections. In section one, we outline the challenge of coastal zone management, and highlight some key themes and insights from the STS, STP and extension literature, before proposing a set of broad principles that may guide the application of science and its integration with other forms of knowledge in coastal zone management. In section two, we outline a sophisticated, applied science initiative of CSIRO and the University of Tasmania, the Inshore Network for Observation and Regional Management: Derwent–Huon, known through its intriguing acronym INFORMD. The fundamental aim of INFORMD is to provide quality modelling and monitoring outputs of biogeochemical flows and processes, presently in south-eastern Tasmania, in order to inform decisions across a raft of policy and management concerns in the coastal zone. Key outputs of INFORMD are currently becoming available as the initiative reaches the latter stages of its development. Finally, in section three, we draw on the principles outlined, to consider the opportunities for improving the use of INFORMD in coastal management. In this context we explore how our principles for linking knowledge and action might be applied to enable effective and useful application of INFORMD in decision-making for coastal zone management.

Following Pielke (2007), we suggest that there is always more than one strategy available to scientists and scientific agencies to engage with decision-makers and stakeholders. We argue that scientists and scientific agencies should thoroughly consider aspects of the available strategies in order to make informed decision about how best to link their scientific outputs, and more broadly their knowledge, with coastal zone management. We suggest that this process should include explicit decisions about how the principles detailed below will be handled by scientists and their organisations. Through discussion of the potential risks of taking specific approaches, researchers will be able to refine their preferred mode of engagement and address tensions within their teams. We acknowledge that such discussions and choices may not sit comfortably with all researchers. Yet we argue that consideration of these issues influences the extent to which scientific information can ultimately become useful and useable (Cash *et al.* 2003).

THEORETICAL FRAMEWORK: THE CHALLENGE OF MAKING USEFUL AND USEABLE SCIENCE

The challenge of useful and useable science for coastal zone management

Coastal zone management is about much more than solely technical issues; issues of power, equity and trust are central, and neither science nor scientific information are removed from such issues (see Chapter 2). Effective coastal zone management thus requires considerable attention to ensure that scientific knowledge can be useful and useable in the context of diverse values and policies, and in relation to issues of equity, power and trust. If such a challenge is to be embraced, it will need to be both theoretically sound and practically applicable. This is especially the case as increasing pressure on coastal systems makes traditional approaches to management less effective.

A substantial body of research sheds light on how science becomes useful and useable, and what prevents this from happening. We draw on this empirical and theoretical work, specifically from science and technology studies (STS), agricultural extension and science and technology policy (STP) as a foundation for a set of principles for creating useful and useable science for coastal zone management. Far from providing a thorough review of these fields, which is well beyond the scope of this chapter, we have synthesised some of their central findings to outline the principles below. First, though, it is helpful to briefly highlight the tenor of the scholarship across STS, STP and extension.

Recent STS scholarship focusing on the way science and scientists interact with politics, policy, the law and the general public, can usefully inform engagement initiatives for science programs. Scholars have used various approaches, ranging from detailed ethnographies of 'science in action' through to historical and philosophical treatise and quantitative bibliographic analyses. Such empirical research has consistently described diverse social and cultural processes that enable trust and consensus to be developed to drive scientific advances. Evidence, while crucial, is not the be-all and end-all of science. Scientific processes, like all human processes, are imbued with social and cultural facets which make them consistently more complex than philosophers' visions of how science *should* operate. The values and commitments of scientists form an often implicit backdrop to how non-scientists relate to science, and to scientific organisations and information. Thus trust in science is by no means automatic, but related to historical relationships, predicated by repeated interactions, underpinned by reciprocity. STS research indicates that trust depends on the language people use to accommodate one another's belief systems, values and worldviews, or to define boundaries between them. For example, a commonly held perspective about why people do not act upon scientific knowledge is that they simply do not have sufficient scientific understanding. This 'deficit model' of the public understanding of science has been refuted, with many case studies indicating that issues of trust are more central to rejection of science. Yet much of the work in STS examines regulatory science and controversies in which an adversarial situation precedes scientific interaction with communities or policy-makers, and this adversarial feature of engagement often frames the ways people can and do relate. In more collaborative contexts, relationships between scientist and lay publics are much more mutually engaged. A set of key lessons with regard to such mutual engagement comes from agricultural extension.

Despite a sharp decline in public investment in extension, there is a growing acceptance within rural social research and extension studies that successful agricultural innovation, informed by science, will require close engagement between scientists and agricultural decision-makers, often through the process of extension. Through extension, at least ideally, researchers can come to understand how information and innovations can fit within current farming systems. Farming systems in this context are taken as all the physical, human, social, cultural and economic practices that comprise the operation of agriculture. Thus, for some rural sociologists, the flow of information between farmers and scientists is at least as fundamental to innovation as technologies themselves. Increasingly, in fact, the term 'technologies' is used to include social processes as well as hard technological tools (Jasanoff 2003); so, for example, *Decision* Support Systems were reconceptualised as *Discussion* Support Systems (Nelson *et al.* 2002). The 'linear model', in which basic research provides information to applied researchers who develop innovations which are then extended to farmers (RD&E), is rejected by most people involved in contemporary extension (SELN 2006). Instead, the development and uptake of innovations arises from dynamic and interactive exchange of knowledge between different participants (Roling 1985, 1992). Agricultural systems are increasingly considered to include the technical work of farming, together with social and cultural aspects of farming and the ways that specific groups of farmers think and talk about themselves: what defines them with respect to others (Vanclay *et al.* 2007). These sorts of narratives about identity, farming 'styles' and practices often describe historical associations within communities, with others (such as city folks) and with the places they live and work. The prevalence of place in the ways people talk about themselves and what they value has resulted in substantial interest in the role of place and placed knowledge in agricultural innovation. Another persistent theme relates to the role of 'champions 'or 'opinion leaders' who can substantially affect how agricultural communities change over time. It is common, for instance, for agricultural scientists to talk about and engage with the 'top five per cent' of farmers, who are considered the leaders or innovators (Rogers 2003). Yet, within broad farming communities there are likely to be other, less technical, farming communities who innovate in very different ways (Leeuwis 2004).

When the well-known Australian ecologist, the late Peter Cullen (pers. comm. 2004) quipped that 'for every PhD there is an equal and opposite PhD' he was, perhaps unwittingly, summing up a key observation of science and technology policy: that scientific research can be conducted and applied in diverse ways that do not necessarily serve to further knowledge or reduce our collective uncertainty. This work refutes a widely held assumption, enshrined in many scientific and policy documents, that the 'linear model' is broadly applicable to the way science influences policy. If there is uncertainty or controversy about an environmental issue, for example, the common response is to fund scientists to fill 'knowledge gaps' in order to resolve these problems and thus enable decision-makers to articulate clearly what can and should be done. Yet, analysis of the processes involved in resolving such controversy reveal a very different picture of the role of science. Climate change is the classic example. Billions of dollars are invested annually in detection and attribution of climate change and modelling of the global climate system in order to resolve uncertainties around future climate change impacts. Yet there has long been strong consensus among climate scientists both that mitigation of greenhouse gas emissions is urgently required, and that 'proof' of anthropogenic climate change *per se* is not scientifically possible (Oreskes 2004). The notion that more and better science can eliminate controversy is often simply wrong (Sarewitz 2004). Nevertheless, analyses of instances in which science has been successfully applied have described how knowledge is made relevant, credible and legitimate for end users through different forms of engagement across traditional boundaries (Buizer *et al.* 2010; Cash *et al.* 2003; Leith 2011). From such work a variety of potentially successful models of 'boundary-spanning functions' have evolved, and started to gain traction.

Across all these research domains – STS, STP and extension – a consistent theme can be summed up as follows: application of scientific knowledge always hinges on trust. Relevance of information and the scientific rigour by which results were derived are important, but the social processes that create trust are crucial to the uptake of science in decision-making. Yet fostering trust, we believe, should not be seen as an end in itself, but an outcome of ethical, equitable and transparent engagement between scientists, stakeholders and specific decision-makers. Within STS it has been convincingly demonstrated that such trust forms the foundation for modern science (Shapin and Shaffer 1985). In fact, trust, rather than experience or observation, is the basis for much of our individual and collective knowledge, within science as in the broader society. Despite the foundational precepts of 'organised scepticism' or 'falsification' within the philosophy of science, many aspects of knowledge are not treated with scepticism or regarded as falsifiable. In practice, methods, materials, technologies and theories are often necessarily embraced by scientists in order that their science can move forward (Law 2004). This relies on trust.

Drawing on the literature outlined above we have developed principles that we hope will assist biophysical scientists to contribute to policy and practice through engagement programs that are yet to be fully developed. We recognise that these engagement processes will need to be tailored to and adapted to specific circumstances, and will often be constrained by resources, institutions and other commitments. For instance, there are cases in which decision-makers will discourage scientists from analysis of policy options for political or other reasons. The conditions under which scientists work can also present a constraint to such engagement. For instance, the metrics of success in a research career rarely include the degree to which scientific output has informed public or private decision-making. Until such institutional impediments to interactions between science, policy and practice are remedied, scientists will often need to work in spite of the system rather than because of it to make their research become useful and useable in decision contexts (Campbell 2006). The choice to undertake such work is not a simple or straightforward one, but, we argue will often result in greater legitimacy of scientists and their work, and thus improved uptake of science for coastal zone management.

Cummins and McKenna (2010: 798) identified how such legitimacy can be developed through: developing a problem-driven agenda; co-producing knowledge; using an interdisciplinary approach; addressing system complexity; focusing communication and research activities at a local scale; and facilitating a process of social learning. Their focus on 'principles of sustainability science' provides useful insights into robust engagement between science and decision-making. Yet, we expect that such principles may not be applicable to all action situations or may lack the flexibility necessary to accommodate different contexts. For instance, they appear to assume that social learning can be accommodated within existing contests of interests, values and power relations. We would suggest that issues such as resourcing and commitments to particular priorities may reflect longstanding relationships between power and knowledge that can prevent effective engagement. We hope that our principles, at a minimum, provide the basis for dialogue and debate within scientific programs, and from such internal discussion enable the development of context-appropriate engagement. We do not intend to prescribe idealised forms of engagement that may be unachievable. Rather, the principles are presented here as points of departure for discussions about how to shape engagement in science programs.

Five principles for making useful and usable science

1 Enable transparency about the different forms of risk and uncertainty.
2 Enable stakeholder engagement in framing issues.
3 Address the potential for controversy and conflict.
4 Consider social and cultural boundaries, and their implications for knowledge and decision-making.
5 Recognise common heuristic errors and cognitive biases.

Principle 1: Enabling transparency about different forms of risk and uncertainty

Risk, uncertainty, indeterminacy and ignorance are often lumped together as uncertainty, yet they have qualitatively different characters and need to be communicated in different ways. Uncertainty implies that the things we don't know can be known, and only require more research to reduce uncertainty. Yet there are many instances where we simply don't know what we don't know (ignorance), or in which things are unknowable (indeterminacy). Risk analyses, the calculation of formal probabilities of particular happenings, tend to be targeted at phenomena that are well enough understood by scientists, rather than those that are relevant societal concerns. For example, seasonal climate forecasts provide probabilities of receiving 'above median rainfall' for a period of time, rather than forecasts of how much rain will fall, where and when during that period. Such limitations mean that decision-makers must often adapt the best available information to their decision needs.

Different forms of uncertainty need to be made explicit when communicating the results of scientific outputs to avoid misuse of these outputs, and where uncertainty, ignorance or indeterminacy are high, a specific form of science may be required to make legitimate knowledge. In recent decades some attention has been directed towards identifying the types of science that may be needed to address the types of challenges currently being encountered. Funtowicz and Ravetz's (1993) influential contribution distinguishes between core science, applied science, professional consultancy and post-normal science. Post-normal science, they argue, should be employed where uncertainty and/or stakes are high, because it can explicitly address the important role of values in science and decision-making in the context of uncertainties (Funtowicz and Ravetz 1993). It does so, in part, through 'extended peer review', in which citizens can contribute to scientific knowledge through various forms of engagement (see Principle 2).

Decision-makers often want certainty in order that their decisions are robust. Politicians often talk about facts as if science can deliver these without problem. These forms of demand and rhetoric can appear to place scientists in an invidious position: either detail the uncertainties associated with findings and risk having knowledge characterised as imprecise, or claim to have greater certainty than actually exists. Yet there are other options. Scientists are often well placed to explain how robust their predictions or findings are in the context of particular policy or decision options. For instance, in the case of developments in the coastal zone, researchers might be able describe how their information has a bearing, the range of possibilities or probabilities of particular impacts and how these could be ameliorated by particular interventions. These may not be direct outputs of monitoring or modelling, and may even be qualitative interpretations but, especially in the early stages of application of scientific information, they can give decision-makers a feel for the knowledge that is behind a set of scientific outputs, their limitation and their applicability. Although demand to clarify uncertainties around outputs may be initially high, early and thorough engagement can avoid misapplication of these outputs, and build trust in the knowledge and rigour on which they are based. In many respects scientists themselves need to trust stakeholders to see the value of their work, despite its uncertainties, and come to see its usefulness through engagement with the possibilities of its application.

Principle 2: Enabling stakeholder engagement in framing issues

Scientists often consider their role in policy discussions as simply providers of data and information to decision-makers or stakeholders, and that these groups and individuals are the ones that make the decisions. Yet many complex processes can be involved in the translation of information into knowledge, and of knowledge into decisions to respond to issues. The framing of issues is fundamental because it defines who and what are relevant to the decision at hand and, thus what the scientific problem to be addressed is. The process of defining problems for scientific investigation can be used strategically to include and exclude certain sources of information, perspectives, values and people.

Commitment to particular approaches to problem definition affects issue definition in diverse ways. Managers and scientific researchers must often work hard for their own processes of framing problems to be independent of politics, yet policy relevant. For instance, issues are often times framed as problems such that there will be substantial uncertainty around the technical resolution of that problem. Uncertainty can be mobilised to justify policy inaction, precautionary measures or increased research effort. Scientific uncertainty can also be used rhetorically to place the burden of proof on proponents or opponents of a development or policy change. The way this burden of proof is allocated appears to be variable between cultures and communities and can change over time, but it varies generally between privileging the *status quo* or taking a precautionary approach (Jasanoff 2005; Oreskes 2004).

When issues are framed as problems the degree to which that problem is constructed in technical or scientific terms can also influence whether the process of inquiry to resolve the problem is inclusive or otherwise of different perspectives, knowledge systems and values. Issues associated with the framing of 'problems' include the following:

1 Scientists frame questions in terms of the methods they have at their disposal, or those that enable them to say something definitive about the results.
2 Other stakeholders may have knowledge that makes the scientific framing of specific questions highly problematic.
3 Problem framing is orientated by values (problems are rarely solely technical), so defining problems requires careful mediation, especially via processes that make values explicit and clear.
4 Focusing communication on groups and individuals who are technically literate can have political implications. It may be easier to explain concepts and the meaning of visualised data to technical specialists, but they will often already see problems as fundamentally technical and may not consider underlying ethical, political and judgement-based issues, which might be raised by, but not answerable by the data. For instance, an apparent trend in an environmental flow may not be statistically significant but may lead some to ask, 'What if the trend continues?' This may be a highly relevant policy consideration, but one that cannot be addressed with current data.
5 Finally, and perhaps most fundamentally, it is also important to acknowledge that what scientists consider to be worthy of investigation may not address the issues of interest and concern to stakeholders and decision-makers. Therefore, if science is to be relevant it needs to be able to address the issues of broader public concern, as well as matters of scientific curiosity. Engaging with stakeholders and decision-makers provides a means for identifying the issues and concerns to build societal relevance alongside scientific merit.

Principle 3: Addressing the potential for controversy and conflict

Because liberal democracies are underpinned by a respect for individual freedoms and values, science is not necessarily given special authority when it comes to the politics of environmental management. Rather, policy-making processes are often concerned with seeking the 'least worst' ways to chart a course through a minefield of competing values and priorities. As Hajer (1995: 2) put it, policy is the means by which 'modern societies regulate latent social conflicts'.

The work of scientists is often funded, undertaken or considered in the context of these social conflicts. Therefore, despite any attempts by scientists or scientific organisations to be impartial and remain objective in the way they conduct and publicise research, their findings are often the subject of dispute. Science is always practised within the context of wider social and political debates. Under these circumstances, research findings or 'facts' do not speak for themselves, and instead are interpreted. Even where a particular finding is uncontested, the implications and significance associated with such a finding varies considerably among stakeholders (Rein and Schon 1993). Scientific outputs are also championed or discredited by people, depending on how the research fits with their ideological perspective and interests. Scientists therefore need to be aware of the potential for controversy.

Part of the reason that science can create rather than resolve controversy is the societal power of science as a way of getting to grips with the world, and because what we know has implications for how we live. Therefore, in saying something about the world, scientists are either implicitly or explicitly saying something about how we should live in it (Jasanoff 2004). While bare-faced advocacy can undermine credibility of science, there is space between discussion of evidence and advocacy, and this can be an avenue for scientists to engage in public discussion without simply representing nature. For example, assumptions about social norms underpinning human behaviour are often used to justify the research agenda in applied research. Risk management is a classic example of this. If individuals are considered to be calculative agents, then they will need data with which to populate their assessments of risk about what they do, when, where and how. This view of human agency creates an expectation that there is a ready audience for scientific assessment of risk. Thus there is a *prima facie* argument for public investment in such applied scientific research to produce risk information as a public good.

We do not claim that this view is wholly mistaken, but it is a vast simplification of how scientific knowledge is adapted and applied in decision-making. Close examination of how scientific knowledge is applied in specific contexts reveal the potential dangers of assuming that risk analyses produce consistently positive outcomes. A loading dock approach to scientific knowledge, in which scientists presents information ready-made to decision-makers (Cash *et al.* 2006) can thus create 'knowledge risks'[1] that can result in the outputs of public good science having negative societal outcomes. An example of such knowledge risks is hazard assessment, which indicates inundation risks that are hard to interpret, and may result in declines or increases in property prices that are inconsistent with the risk, or the potential for information about a person's genetic characteristics or health status to be used in ways that results in the person being penalised or marginalised. On the other hand, when the norms or practices surrounding such risks are derived through interaction and open dialogue between stakeholders, scientists and decision-makers, there is more likelihood that the science will be sensitive to the effects that it might produce, without compromising its credibility.

This emphasises how co-production is not just about linking scientific and other forms of knowledge, but about acknowledging and taking responsibility for the social and political effects of knowledge within social processes. While we expect that co-production through such deliberative processes is a more effective path to dealing with controversy than the loading dock approach, it is definitely neither cheap nor easy to accomplish. This is, in part at least, because there is a variety of boundaries across science and society that makes collaborative problem definition and problem-solving extremely challenging.

Principle 4: Considering social and cultural boundaries and their implications for knowledge and decision-making

One of the common observations about the way in which research and government agencies operate is that both have silos that restrict their ability to cross-fertilise and have influence outside of their bounds. Although this is a commonly recognised problem, there is rarely any formal analysis or description of what the boundaries between these silos are, how they operate and how they are maintained or crossed by individuals or groups (Gieryn 1983, 1999).

There are numerous forms of social and cultural boundaries that are relevant to the coastal zone. Disciplinary boundaries within biophysical sciences and between biophysical, social science and the humanities relate to different approaches to problems and the various ways of knowing that are considered across these disciplines. Boundaries between science and policy, and science and the different sector of the community at large, may similarly be built around ways of knowing and different approaches to tackling problems. One potentially useful way to consider boundaries is by thinking through different categories of communities: communities of practice, communities of place and communities of interest. In many ways the process of engagement in science seeks to develop or strengthen communities of interest – in this case the point of interest is coastal zone management. There may be various communities of place (made up of people who live in particular localities) and practice (whether policy, management, scientific, business or recreational) who are interested in specific aspects of coastal management. Engagement that can inform or help develop a coherent community of interest has the potential to build human capacity in terms of knowledge and skills, but can also build social capital and trust across what might otherwise be disjunct communities, potentially working at cross-purposes.

Another useful way of thinking about boundaries is in terms of how knowledge is made variously salient, credible and legitimate across them (Cash *et al.* 2003). These terms (defined in Box 6.1) have become widely used in recent years, and have formed a strong linkage between STS and people concerned with the societal application of science. Salience, credibility and legitimacy should not be considered as objective qualities of information but based in perception; in line with the argument for thinking about place and context, what appears relevant to one individual or community may not be relevant in another. Yet, because such matters are rarely discussed explicitly in the public domain, they are often hard to tackle explicitly through open discussion.

Place and locality are also important considerations when thinking about boundaries and linkages across them. Placed communities, such as those in regional or rural areas, can exhibit strong social ties locally, which can influence their identities and the forms of knowledge and information that are considered useful and useable. Extension-related research, for instance, has demonstrated how farm trials become less relevant to farmers as the distance of the trial from the farmer increases (Ridley 2004). Conversely, science concerned with general trends and patterns at regional or national scales may be of benefit to decision-making at a national or statewide scale, but of less use at a local level. For example, broad-scale catchment modelling may provide a useful understanding of basin-wide groundwater levels and flow directions, but will be unable to provide insights into the operation of groundwater systems at the subregional or paddock levels.

Yet geography is only one measure of distance. Organisations may also be institutionally close or far apart; and people across organisations may have similar or different belief systems, worldviews and ways of knowing, and ways of speaking, which will affect the ease with which they can understand each other or find a common language or conception of problems and pertinent information to addressing them.

Boundaries between scientific and policy cultures are substantial, and tend to be dealt with through relationships that allow for complex negotiations of authority (Jasanoff 1987).

Box 6.1. Three key concerns for boundary spanning science

Salience

The relevance of information in the context of decision-making, including the timeliness of information and whether it is directly translatable into the mental models and applied thinking of practitioners; whether they are policy-makers, managers, fishers, farmers or members of the community.

Credibility

The methods that are used to create knowledge and how reliable they are considered to be within specific communities. The usual way scientists consider credibility relate to methods that are currently accepted within a particular discipline. Yet in different knowledge cultures (indigenous, lay or managerial) there may be very different approaches to evaluating credibility. Farmers, for instance, tend to prioritise empirical or experiential knowledge that has been generated locally over more universal and abstracted knowledge.

Legitimacy

The fairness, equity, inclusiveness and transparency of the processes of knowledge production. These processes can create a sense of ownership or alienation from science organisations, and are fundamental to how the values of scientific enquiry of particular organisation and individual are viewed by the wider community.

Scientific information is almost always made and used in the context of relationships among people and organisations, which influence research priorities and the selection of research methods. Scientific cultures tend to pay closest attention to issues of credibility, rather than salience or legitimacy, with the assumption that 'the scientific method' itself produces legitimacy. Yet far from giving science automatic authority, the legitimacy of science depends on both perceptions of fairness and transparency of the social practices of scientists individually, collectively and historically.

Managing the effects of boundaries always presents a major challenge for scientists and scientific organisations, as well as public sector organisations. Yet such work is often done in an ad hoc fashion, reactively rather than strategically. It is not generally something that scientific agencies excel at. Cash *et al.* (2003) suggest that to undertake this work well requires that organisations have the capacity to convene, mediate and translate across stakeholder groups and their respective knowledge, values and interests. Convening and mediating are relatively straightforward to define, though can be difficult to accomplish; they require bringing groups together and facilitating open dialogue about how knowledge can be implemented in action. The meaning of translation is more complex. While it can have a literal meaning (such as from translating from French to English), it can also be considered as a process in which new meanings are derived by linking previously separate things or people (Latour 1987). The work of convening, mediating and translating may not appeal to many scientists, and is certainly not core business for many, but in the context of applying complex scientific information to difficult societal problems these sorts of processes of engagement are increasingly viewed as prerequisites for ensuring appropriate application of scientific knowledge.

Principle 5: Recognising common errors of judgement and cognitive biases

Assessment of risks is underpinned by commitment to use the 'best available scientific knowledge' in a rational manner. Yet cognitive science provides substantial evidence that challenges the notions that humans are rational in such a calculative way. People are generally not able to make good sense of probabilities. The work of Kahneman and others (e.g. Kahneman *et al.* 1982; Kahneman and Tversky 1996) has lucidly demonstrated that, even among those trained in statistical analyses, biases and cognitive illusions are rife when people make on-the-spot interpretations of probabilistic information. And this work highlights the need for consideration of 'heuristic errors' (or errors of judgement) and 'common cognitive biases' when communicating scientific risk. Some examples that highlight how 10 key errors and illusions can affect decisions are summarised in Box 6.2 (adapted from Nicholls 1999).

These common heuristic errors highlight that communication of science, and interpretation of scientific data and information by both scientists and lay people, is more complex than is commonly appreciated or acknowledged. Importantly, miscommunication can occur across a wide variety of situations, including where researchers from different disciplines are working together, or where researchers are communicating their work into policy or other decision-making processes. If the intention of scientists is to have their research findings contribute to the public good, then they need to be interpreted as intended, which means that scientists have a responsibility to be aware of potential pitfalls and take steps to minimise them. Close engagement with stakeholders and close working relationships with relevant communication experts may be useful in such circumstances because it enables scientists to pick up quickly on what errors or biases are at play and language that might be useable to reframe information to avoid these biases in later communication. However, even without such engagement it is often useful to repeat messages in different ways to reduce the risk that a single phrasing is not consistently misinterpreted. For example, an analogy may be a powerful way of making a complex concept make sense to lay people, but it also serves as an anchoring device and can reduce the capacity to see problems from more than one perspective.

To conclude this section, we consider that coastal science is more likely to be useful and useable if it fosters trust, with factors that contribute to fostering trust, including: being clear about risk and uncertainty; understanding the context within which research is being undertaken; considering the effects and implications that might arise from the research; engaging with stakeholders (ideally through collaborative arrangements) throughout the research process; considering boundaries and their implications; being aware of the potential for controversy; and recognising the effects of heuristics and cognitive biases.

CONTEXT: INFORMD AND COASTAL ZONE MANAGEMENT IN SOUTH-EASTERN TASMANIA

In this section we outline the INFORMD initiative and the context within which it has been developed. South-eastern Tasmania includes the Huon and Derwent estuaries and the Bruny Bioregion located in the South-east Tasmania. It includes those coastal and marine areas immediately surrounding the Greater Hobart area, the major population centre in Tasmania. The region has significant cultural and natural heritage and is a coherent ecosystem supporting a wide range of habitats and species. It includes major economic activity and infrastructure and the largest and fastest growing local government areas in Tasmania. The region contains a number of non-governmental organisations, ranging from business and industry bodies, Indigenous organisations and community-based organisations focusing on the coastal zone. Despite a range of planning instruments at local government level, and a developing coordinating

Box 6.2. Common errors of judgement and biases that can affect decisions

The framing effect

The way a risk is posed affects the response to it. For instance, two forecasts which ostensibly mean the same things are usually interpreted differently (for example, a 30% chance of coastal inundation is viewed more pessimistically than 70% chance of no inundation).

Availability of information

People often try to convey information through associations or metaphors that are well understood, but can be inappropriate.

Anchoring and adjustment

The position from which an individual comes to a problem affects the way he or she views it. For instance, a particular event may anchor expectations of future events

Underweighting base rates

The combination of different probabilities alters perception of likelihood. For instance, if a model is accurate 90% of the time and it is forecasting, say an algal bloom, then most people may have faith in forecast. But if there is a 10% likelihood that there will be an algal bloom anyway, Bayes's theorem gives a likelihood of correct prediction of 'algal bloom' at 50%.

Overconfidence

People tend to be unjustifiably confident about their response being right. A related problem is optimism about personal risk: the sense that people think 'it will not happen to me'.

Added information biases

Extra information may not produce better assessment of a forecast. It may, instead, lead to confusion, especially where information is conflicting.

Inconsistent intuition

Formal models have often done better at predicting the outcome of complex interactions than intuition based on experience. However, mathematical models can also be drastically wrong.

Hindsight and confirmation of bias

If someone believes in the accuracy of a model or assessment, then inaccurate predictions are likely to be downplayed, while accurate ones are celebrated.

Belief persistence

One accurate or inaccurate forecast can lead to a belief in the accuracy or inaccuracy of a forecast system, which is likely to persist even following later inaccurate or accurate forecasts.

Group conformity and decision regret

Sometimes referred to as *groupthink*, conformity can lead people within a group to concur with each others' judgement, for instance, to accept or reject a forecast. Once a group has formed a position, an individual may find it hard to stray from this position without being ridiculed. Thus, group conformity is described as the easier option than decision regret.

framework for environmental monitoring, the region currently lacks an overarching coastal policy, following the revocation of the State Coastal Policy. South-eastern Tasmania is a microcosm of the issues facing coastal development globally and elsewhere in Australia; that is, an increasingly diverse and intense range of human activities, fuelled by economic prosperity, technology and population growth, all in a context of climate change. This region also has a well-developed science and management infrastructure, making it an ideal location to develop and demonstrate how these issues may be better addressed.

The Derwent–Huon Region

The Derwent–Huon Region, encompassing the estuaries of the Derwent and Huon rivers, is fundamental to the cultural, natural and economic heritage of Tasmania, because it contains a wide range of ecological systems and industries. The Derwent estuary extends from New Norfolk south to Iron Pot lighthouse (see Figure 6.1), and encompasses the Hobart metropolitan area. The Huon estuary stretches from Huonville to the D'Entrecasteaux Channel. Both rivers support a range of uses and users, and are experiencing increasing coastal development pressures.

The Derwent and Huon rivers form an integral part of the Bruny Bioregion, which contains a particularly complex and convoluted coastline, with an abundance of islands, peninsulas, embayments and estuaries. Clear oceanic water influences much of the exposed coast. However, water from the Derwent and Huon Rivers substantially structures the biotic communities of the bioregion such that they can be characterised by the influence of one, both, or neither of these systems (Resource Planning and Development Commission 2006: 118).

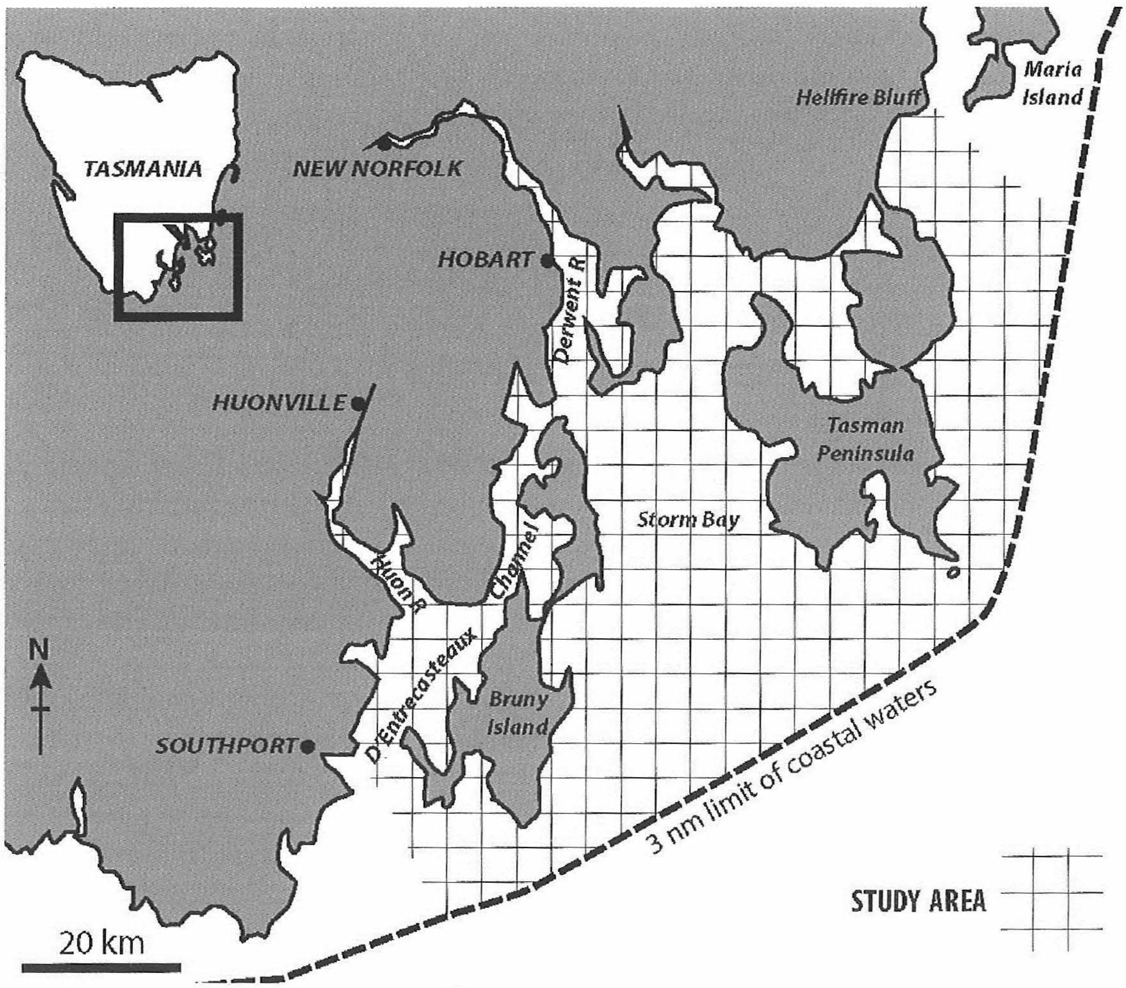

Figure 6.1. The Inshore Network for Observation and Regional Management: Derwent–Huon (INFORMD) Region. This encompasses the Bruny Bioregion.

As the INFORMD research agreement noted:

The joint estuary for these rivers and the adjoining oceanic coast supports high conservation value species and communities (e.g. several marine mammal species, seabirds, sea-eagles, penguins, giant kelp forests, marine protected areas), introduced marine pests (e.g. Pacific sea star), several large marine industries (e.g. aquaculture of fin-fish and shellfish, commercial fishing for abalone, lobster and fin-fish, wooden boat-building), and rapidly growing recreational and tourism use. The joint estuary and Derwent River also provides shipping access to the port facilities of Hobart (INFORMD 2008).

The Derwent and Huon estuaries are affected by a number of environmental issues. These issues are most significant in the Derwent. The environmental health of this estuary and foreshore areas has been affected by a legacy of past industrial discharges including heavy metal contaminants (mercury, lead, zinc and cadmium) and is affected by expanding urbanisation. In recognition of these challenges, and the need for a strategic and coordinated planning approach across all levels of government, the Derwent Estuary Program (DEP) was established in 1999.

The DEP is a regional partnership comprising both the Tasmanian state and local governments in conjunction with commercial and industrial enterprises and community-based groups. The DEP develops, coordinates and implements framework agreements and practical initiatives aimed at the reduction of water pollution, habitat and species conservation, the monitoring of river health and enhancing the use of the Derwent foreshore areas. DEP projects are centred around five key areas: the management of human pressures; protection of ecosystems; conservation of cultural heritage; enhancement of human uses, and the promotion of understanding, awareness and participation. The program has been nationally commended for excellence in coordinating these initiatives, and for successfully engaging a wide range of stakeholders. The major partners and sponsors involved in the program are the Brighton, Clarence, Derwent Valley, Glenorchy, Hobart and Kingborough councils, the Tasmanian State Government, Southern Water, Tasmanian Ports Corporation, Norske Skog Boyer and Nyrstar Hobart smelter.

An Environmental Management Plan (DEP 2009) guides DEP operations, which seek to enhance and protect the estuary's values and to inform and involve the community in the process. The DEP undertakes a range of monitoring and science activities, publishes results in annual report cards, as well as more comprehensive five-yearly State of the Derwent Estuary reports, and provides quarterly newsletters aimed at keeping stakeholders informed on recent developments.

The Derwent Estuary Environmental Management Plan 2001 indicates that 'contamination of sediment within the Derwent is a significant issue particularly with respect to heavy metals and organic matter'. Derwent estuary sediments are among the most contaminated sediments in Australia with respect to mercury, lead, zinc and cadmium. Principal goals of the DEP include taking action to ensure the ecological protection of the estuary by coordinating and supporting monitoring activities and scientific investigations: to promote and enhance its range of recreational and commercial uses and values; to inform the public via the regular compiling and distribution of reports; and to facilitate community awareness and engagement.

INFORMD

The Inshore Network for Observation and Regional Management: Derwent–Huon (INFORMD) began in July 2008 as a joint initiative of CSIRO's Wealth from Oceans Flagship and the then Tasmanian Aquaculture and Fisheries Institute (TAFI) (now the Institute for Marine and Antarctic Studies) at the University of Tasmania. Project documentation indicates that 'INFORMD provides an umbrella program for housing and coordinating relevant existing projects and developing new projects. The overall institutional arrangements will be specified by a Letters of Agreement between CSIRO and the University of Tasmania' (INFORMD 2008). This project developed from CSIRO's extensive work in the region, and particularly the results of the Huon Estuary Study.

The Huon Estuary Study was a three-year project focusing on gaining a better understanding of the biophysical characteristics of the Huon River system, which aimed to provide scientific advice to guide the development and management for the region's aquaculture industry, and the future sustainable management of the waterway. The report proposed the development of an automated, catchment-scale monitoring network that would meet the broad requirements of the region, providing data to a range of stakeholders and allow the development of products for environmental forecasting and scenario testing (CSIRO Huon Estuary Study Team 2000: 274). Advances in technology have allowed the development of integrated low-cost, near real-time environmental monitoring systems. INFORMD combines these with sophisticated modelling and simulation available under the Environmental Modelling Suite.

INFORMD has been designed to improve delivery of modelling products for management of the coastal marine environment. South-east Tasmania was chosen for the test site of this project, because of the existence of numerous modelling products and knowledge of the system. There was also substantial stakeholder support for the system characterisation that such modelling can deliver. Specifically, local councils and state regulators whose legislated role is, respectively, to manage water quality and the growing aquaculture industry, saw substantial potential value in the provision of accessible modelling tools for management.

INFORMD's specific objectives are to:

- compile, extend and integrate the scientific information and understanding of the marine and coastal ecosystems of the Derwent–Huon region
- develop and demonstrate practical, science-based methods that support both sectoral and integrated regional planning and management for ecologically and economically sustainable development of the Derwent–Huon region
- increase the scope and efficiency of monitoring and delivery of decision-relevant information to sectoral and regional decision-makers for the Derwent–Huon region
- Assess sustainable development options and strategies for the Derwent–Huon region
- Develop and demonstrate observation methods and information delivery tools that are transferable to coastal management elsewhere (INFORMD 2008).

The near real-time model is currently operational, and generates an ongoing and increasingly long archive of the ocean state that is always up to date. This archive can then be accessed for analysis or re-running scenarios including biogeochemistry and sediment transport. These scenarios may be run using either a fully coupled hydrodynamic model, or for longer scenarios, coupling to a transport model may be more appropriate.

The program has formally recognised a number of limitations of the application of INFORMD: 'there is difficulty with critical elements in the monitoring, interpretation and provision of timely scientific advice to industry and managers' (INFORMD 2008). Additional challenges arise from the sectoral nature of management and scientific research. Research is generally focused on specific problems or issues, with monitoring designed to provide information for site- or sectoral-specific purposes. For example, 'in some cases the information is collected but not easily accessible and in other cases key information is not collected. And overall there are not the tools available to illustrate and explore the options for regional development' (INFORMD 2008).

In an attempt to provide strategic and management relevant outputs INFORMD set up a Partnership Group to liaise with the Tasmanian Government departments, local government, the Derwent Estuary Program and the salmonid aquaculture industry. The Partnership Group has established two working groups targeting aquaculture and heavy metals as priority areas of concerns. These working groups aim to link the science with research users. Aquaculture is a substantial industry in the Huon and Derwent regions, and has longstanding links with science programs in CSIRO and the University of Tasmania. Monitoring heavy metals in the Derwent involves industry and other stakeholders, largely through the DEP.

Yet beyond its Tasmanian testing and applications, INFORMD is a 'building blocks' program within which CSIRO is putting together the elements of a salient, credible and legitimate information and modelling framework that can be introduced into other regions and put into operation with a known cost in terms of calibration, validation and verification. Although South-eastern Tasmania is still used for the piloting of new model variants, the model framework has been 'dropped into' South-eastern Queensland and other regions of interest with a reduced up-front overhead. The initiative also allows for rapid transfer and calibration of marine sensor networks into new areas. For both monitoring and modelling INFORMD is using the South-eastern Tasmania area to develop the components that will be applied in other regions.

LESSONS AND IMPLICATIONS FOR COASTAL MANAGEMENT

In this section, we draw upon the principles outlined above to consider first, broad implications for scientific engagement programs to improve science uptake and applicability in coastal zone management, and second, how these principles might be applied to the INFORMD initiative. We also consider some broader implications associated with knowledge in action. In doing so our intention is to open up areas for further discussion and exploration, rather than outline a set of prescriptions.

Broad implications of principles for coastal management

The five principles detailed above, we suggest, are useful for developing an approach to engagement via thought and discussion, in the first instance within a science program, potentially with the contribution of social and institutional researchers who are familiar with the issues surrounding the science program. This discussion, at least initially, can be orientated by a series of questions that can effectively ground the principles in the action context (Box 6.3). Discussions provoked by these questions can help to determine the approach to engagement that will be most appropriate and the resources that are available and necessary to undertake it. This initial planning should itself allow for flexibility, and ensure that formative evaluation of the engagement process is embedded in its design to enhance the ability to reflect on lessons learnt, and to be able to account for the effectiveness of the approach adopted. It is also important to consider how communities can engage science in designing and/or developing science programs in areas in which scientific knowledge is partial or nonexistent.

In the end, the choice of an engagement strategy casts the principles as providing options for selecting approaches on a continuum between 'loading dock' and 'co-production'. We do not claim that any specific point on this continuum is ideal, but that the choice of this point ideally should be made explicitly. This way the effectiveness of a particular course of action and engagement can be evaluated against the rationale for its selection.

Potential opportunities for INFORMD

INFORMD started as a science program and was initially a technical concern – the key questions were how to monitor and model the biogeochemical processes – and notions of credibility were driven by scientific concerns about methodology rather than local and regional problem frames. Although the project rationale is very much geared to addressing issues relating to societal and environmental concerns, these concerns were not systematically outlined in the development or scoping of INFORMD in terms of problem definition. Consequently, with the exception of small groups of stakeholders who speak a similar technical language to the INFORMD scientists, the development of the program to date has largely been framed with reference to scientific concerns. Although this is justified by the exigencies of the program (see above) and is typical of biophysical scientific research programs, it presents a challenge for INFORMD to 'retrofit' the preceding principles in ways that guide its future development and uptake in the social and economic context of coastal zone management generally.

A useful starting point is the systematic identification of, and engagement with, stakeholders with an interest in the issues targeted by INFORMD: the sustainable management of the Derwent–Huon estuary. In this context, stakeholders are defined as 'those individuals, groups, organisations and communities involved in or affected by decisions made to plan and manage coastal areas' (Rockloff and Lockie 2004: 83). This is necessary for at least three fundamental reasons: first, such stakeholders may represent the target audiences for the outputs provided by INFORMD, which means that they need to be aware of the potential contribution that INFORMD can make; second, research outputs need to be presented in ways that make sense to the diverse body of stakeholders if they are to make use of them; and third, recognising that coastal management is not the exclusive domain of science (to some extent all stakeholders engage in knowledge generation, management and use), there is potential value for the INFORMD initiative in drawing on the expertise and insights of stakeholders. In identifying stakeholders, it is also important to consider the diverse roles of different stakeholders, and the range of strategies required to engage them (Reed *et al.* 2009). In designing such engagement strategies there is a need to consider both the social networks within which various stakeholder groups operate, and the more formal institutional processes through which coastal management decisions are made. This would assist in the identification of opportunities to 'piggy back' on existing consultation processes or create new processes, as required.

Without limiting the types of mechanisms that could be deployed, some possibilities include: embracing continual engagement models (Reid *et al.* 2010); collaborative knowledge production (Weichselgartner and Kaspeson 2010); and knowledge brokering (Michaels 2009). Such mechanisms illustrate some of the ways for working across boundaries. In identifying the potential of such processes, we in no way seek to simplify the complexities, or understate the controversies, associated with a more engaged science. Engagement for science programs is considerably more challenging than non-engagement, and thus requires investment and considerable thought. Yet science uptake is predicated by some form of engagement.

In developing its approach to engagement we would argue that the INFORMD initiative can build substantial capacity by working carefully through the principles detailed above and reflecting on how the program goals, values and resources can best serve the constituents of the region. INFORMD has recognised that the DEP provides considerable opportunities for INFORMD scientific outputs and processes to link with governmental and non-governmental stakeholders. Because of its position as a partnership operating within a large portion of the region covered by INFORMD, the DEP could effectively operate as an intermediary between INFORMD and a wide variety of potential information users. Yet such opportunities need to be considered deliberately and carefully to ensure that the outputs of INFORMD can be as useful and useable as possible.

We do not see the principles as separate, discrete criteria. There are complex interrelationships between the principles, yet they provide multiple entry points for thinking through how a particular science program or initiative can and will engage with stakeholders and decision-makers in order to influence coastal management. In this way we can emphasise the interactive nature of good science as well as good coastal management. Further, we consider that the key determinant of INFORMD's future utility is less likely to be based on its technical parameters,

Box 6.3. Some key questions to ask in order to devise engagement programs for coastal zone engagement

Making different forms of risk and uncertainty transparent

- Do scientific outputs contain information about risk and uncertainty that can be appropriately understood by stakeholders?
- How can risk and uncertainty be translated to make them meaningful to stakeholders?
- How do programs deal with differences between information that science can deliver and what stakeholders want?
- Are stakeholders able to contribute to defining outputs and how they are presented? How can they contribute?

Enabling stakeholder engagement in framing issues

- What is at stake for whom?
- How might the science program and the knowledge it produces affect the issues at stake?
- Can the science program change its remit to include other aspects of the system (for instance, to represent different aspects of the system that might better reflect societal concerns)?
- What are the limits of what the science program can include or investigate, and what are the limitations on extending the program?

Addressing the potential for controversy and conflict

- Are there divergent views about problems or issues among stakeholders and/or decision-makers? Are there divergent problem frames relating to their communities of place, practice or interest?
- Are scientific outputs at spatial and temporal scales appropriate for decision-makers and stakeholders?
- Are there possibilities for local validation or discussion of outputs?
- Are there local champions who are already engaged or using scientific outputs? Can they provide examples of how they are using or could use outputs in their decision-making?

Considering social and cultural boundaries and their implications for knowledge and decision-making

- Are there significant conflicts of interest or high stakes surrounding issues on which science has a bearing?
- Is the scientific output open to (mis)interpretation from people with different interests? Can these interpretations be preempted in framing information?
- How will information be translated to ensure it will not be misused or misrepresented?
- Is there potential that knowledge or information from scientific work will result in inequity or uneven distribution of risks and benefits?

Recognising common errors of judgement and cognitive biases

- Given the common heuristics and biases, what are the likely ways in which scientific information from the project or program will be misconstrued or misinterpreted?

and more likely to be based on the extent to which it is embraced within the various decision-making processes that govern the Derwent–Huon estuary.

For the INFORMD initiative the types of engagement that are embraced and implemented will go a long way to defining how INFORMD will be understood and perceived by the various stakeholders and decision-makers, and ultimately used to address relevant issues and questions.

CONCLUSIONS

This chapter has considered the potential for enabling the uptake of science in coastal zone management. In doing so it has highlighted the complexity, uncertainty and potential for conflict associated with coastal zone management. We recognise that, while scientific evidence and advice are crucial to making informed decisions, scientific evidence and advice exists and is used within the broader context of politics, legislative structures and social processes of coastal management. In such contexts, as well as contributing to informed consideration of issues, scientific information can also be sidelined or devalued by decision-makers, or used to create controversy.

With these considerations and the ways they have been dealt with in science and technology studies, science and technology policy and agricultural extension, we have proposed and outlined a set of five principles for improving the communication and conduct of science in coastal management. In broad terms, we made the case for the conduct and communication of science that is embedded in specific social and political contexts. We described how the application of these five principles by scientific research programs can improve the likelihood that the particular knowledge that they produce will be effectively incorporated into coastal zone management, and thus contribute to more effective and adaptive coastal zone management. We also illustrated specifically how these principles might be implemented through the case of INFORMD, a large-scale coastal zone monitoring and modelling program focused on south-eastern Tasmania.

The broader implications of these principles for coastal zone management were also considered, highlighting that the discussions provoked through consideration of the principles and associated questions can assist in the design of programs for a more engaged science. However, we also acknowledge that there are many different variables and factors to consider in deciding on an approach to the conduct and communication of coastal science, such that multiple responses are possible rather than there being one optimal solution. Put simply, there is much to be gained from active consideration of what type of science communication and engagement is to be undertaken. Therefore, in closely considering how science may be conducted, evaluated, interpreted and applied with stakeholders, there is potential to improve the integration of scientific research into decision-making for management and to improve scientific research itself.

Crucially, given the social and political contexts within which coastal management occurs, we emphasise that a more engaged coastal zone science is a necessary but not a sufficient condition for coastal management. A more engaged science can assist in building trust, which is a critical element in all forms of decision-making.

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ENDNOTE

1 This term is adapted from Duncan (2004).

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