Factors influencing the use of decision support tools in the development and design of conservation policy

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Abstract

There are many examples of decision support tools used to analyse information with the intention of assisting conservation managers and policy makers in their decision making. We used structured interviews to collect information on seven case studies from Australia and New Zealand to identify the factors that led to the use (or non-use) of decision support tools when developing conservation policies. The interviews explored hypotheses derived from existing literature on the use of decision support tools in conservation policy. Qualitative analysis of the interviews indicated that key factors influencing the uptake of a decision support tool in conservation policy include the alignment of the tool with the objectives and context of a policy, and its ability to be useful even in the presence of missing data. Two other factors that had been suggested in past literature were not perceived by interviewees to be as important as the above two: the presence of a champion for the decision support tool within the management agency, and the time required to apply the tool. The interviews also

revealed a number of additional factors that influenced use or non-use of decision support tools that we had not extracted from existing literature: ambiguity about policy objectives, the autonomy of the agency, and the employee time costs of applying the decision support tool.

Key words: decision making, decision support tools, conservation policy, Marxan

1. Introduction

A decision support tool (DST) is a platform for integrating, analysing and displaying information to assist decision makers. In support of decisions for conservation management, a DST may provide insights into the consequences of different management strategies or approaches, identify the strategy that will optimise a specified objective, identify knowledge gaps, and provide transparency in decision making. Decision support tools can range from relatively simple to highly complex.

Many DSTs have been developed by researchers with the intention of assisting conservation managers and policy makers. For example, the Ecosystem Management Decision Support system has been widely applied to landscape analysis in the US (Reynolds et al. 2014). The Analytic Hierarchy Process uses pairwise comparisons to prioritise decisions, and has been applied to wide variety of environmental and other decision contexts worldwide (Omkarprasad and Kumar 2006). Marxan (Ball et al. 2009) is a DST designed to identify a set of conservation areas that achieve a particular objective at minimum cost, and can explore trade-offs between conservation and socio-economic objectives. It is the most widely used and known DST for conservation planning, with 6078 users across 182 countries (see www.uq.edu.au/marxan). Another example, the Investment Framework for Environmental Resources (INFFER – Pannell et al. 2012), is a tool for developing environmental projects and prioritising them based on the criterion of value for money. The Framework has been trialled or used by well over half of Australia's 56 natural resource management regions, as well as other conservation organisations in Australia (Roberts et al. 2012), New Zealand (Jones and McNamara 2014), Italy (Pacini et al. 2013) and Canada (see www.inffer.com.au).

Despite the benefits of DSTs, it is often observed that they are underutilised, or not utilised at all, by the intended end users (Nilsson et al. 2008; McIntosh et al. 2011). Several reasons are

cited in the literature, including: different timeframes between policy decision making and scientific research (Briggs 2006; Cvitanovic et al. 2015); research results not providing the specific information needed to support management or policy (Pannell and Roberts 2009; Addison et al. 2013); lack of trust in the researchers by policy makers (Gibbons et al. 2008; McIntosh et al. 2011); low capacity of policy makers to use the research outputs in decision making (Rogers et al. 2015); and the lack of a champion within the policy organisation to enable and encourage uptake of the research results (Mumford and Harvey 2014).

There has been little past research evaluating reasons why DSTs are or are not used in conservation management. A rare example is Addison et al. (2013), who investigated common objections to the use of models in conservation decision-making, based on collating statements made by researchers in the published and grey scientific literature. A common objection reported in the studies reviewed was the policy maker's preference for unstructured subjective judgements from experts, rather than predictive models. The key reason cited for this objection was the resource intensity (money and time) required to deliver useful results using these models.

McIntosh et al. (2011) identified the challenges for DST use in environmental management from the perspective of a group of international experts in environmental DST development. Their recommendations include: to find a champion within the policy-making organisation to promote the DST and to build capacity with the end users and stakeholders.

Past studies on DST adoption in conservation management have provided recommendations based on the researchers' experience. This study investigated the policy maker's perspective on the factors that led to the use (or non-use) of DSTs in the development of key conservation and environmental policies. Bridging the gap between the policy maker's and the researcher's perspectives could offer useful insights that will improve the uptake of DSTs in conservation decision making, and subsequently lead to more effective policy design.

We examined notable case studies in Australia and New Zealand, exploring the factors that facilitated or inhibited DST usage in policy and management, based on interviews with managers and policy makers. The selection of case studies was not intended to be representative of all possible conservation policies; however, they offer a diverse selection and have useful insights that may be transferable to other case studies and policies. The next section presents the criteria used for assessment of DSTs, a description of the case studies and

an outline of the interview process. Section 3 provides results and section 4 is a discussion of key findings and conclusions.

2. Methods

2.1 Factors that facilitate usage of decision support tools

To investigate the factors that influence the uptake and usage of decision tools, we gathered a team of Australian experts in decision support tool design and implementation. Through a literature review and facilitated discussion amongst the team, we identified a range of factors that are likely to promote or prevent the uptake of DSTs in environmental management and conservation decision making. These factors have elements in common with those identified in past studies of the uptake of scientific evidence and models in management and policy for conservation and environmental management (e.g., Rogers et al. 2015; Addison et al. 2013; Cook et al. 2012; McIntosh et al. 2011). The factors were:

- Presence of a champion for the tool within the agency
- Presence of an advocate for the tool outside of the agency
- Existence of a relationship between agency staff and tool experts
- Presence of large numbers of stakeholder groups affected by the policy outcome
- Ability of the tool to deal with missing information
- Whether the tool can be applied quickly
- Whether the policy process allows adequate time for tool use
- Whether the tool capabilities align with policy objectives

These factors were used to develop the questions used in the policy-maker interviews.

2.2 Case studies

We identified conservation and environmental policies as case studies to explore the degree to which the suggested factors influenced uptake and usage of the DSTs. Policies were selected using the following criteria: a decision tool existed that was deemed suited to the policy context; there was published evidence describing the process of policy development; and, relevant policy advisors for each policy were accessible for interview. Both marine and terrestrial policies were identified (Table 1). The policies were applicable at a national scale,

with the exception of Threatened Species Protection in the Australian state of New South Wales, which was included for comparison with its national-scale counterparts. The staff size of the agencies responsible for each policy ranged from approximately 200, for the Great Barrier Reef Marine Park and Australian Fisheries Management authorities, to approximately 2000 for the Australian Commonwealth's Department of Environment. For each of the policies, written documentation and interviews with policy advisors were used to investigate the extent to which the matched decision tool was used, and the factors influencing this outcome.

[insert Table 1 here]

2.3 Data collection

Data collection began by consulting the published literature related to each policy. The sources consulted included peer-reviewed literature, research reports, and government reports and websites. The literature was used to identify the steps taken in developing each policy and any decision tools that were used in policy development.

Policy advisors who had been involved in the development or administration of each policy were then interviewed. The objective of the interviews was to identify the reasons for the use or non-use of the matched DST in development of the policy and to examine the alignment of these reasons with the eight factors identified by the expert working group.

Interviewees were identified in the case study selection process via publications and reports related to the policy and by contacting the agencies responsible for each policy. The most senior policy advisors who had contributed to development or administration of the relevant policy were invited to participate. In total, ten policy advisors were interviewed, between one and three for each policy. The interviews were conducted by telephone and in-person in September and October 2013. Approximately 45 minutes was allocated for each interview. All interviews were conducted by the same project member.

Semi-structured interview scripts were used to direct the flow of the discussions. The script included questions on: the participant's educational background and current role within their agency; the participant's role in the development of the policy; whether a decision tool was used and the interviewee's perception of its level of use (*none*, *low*, *moderate* or *high*); if a tool was not used, whether the participant was aware of available tools and the reasons why

these were not used; if a tool was used, what facilitated its use and the extent to which the tool informed the decision process. The script included prompts related to the factors that the expert working group identified as potential barriers or catalysts to the uptake of decisions tools. The questions were open ended to allow discussion, expression of personal views, and for new themes to emerge. This allowed for the identification of additional factors that influenced the use or non-use of DSTs, other than those anticipated from the literature. As these themes were not defined prior to conducting each interview, they were not raised with every interviewee. The interviews were conducted in accordance with The University of Western Australia's Human Research Ethics procedures (#RA/4/1/6302).

2.4 Analysis

A qualitative analysis of the interview transcripts was performed to evaluate the role that each factor played in facilitating uptake of the specific decision tool available for each policy. Specifically, we applied the categories "*not important*", "*somewhat important*" and "*important*" to identify how the interviewees perceived the influence of each factor. In addition to these assessments, we also provide quotes from the interviews to illustrate the findings across the case studies.

3. Results

The importance of each of the eight factors that facilitate usage of DSTs varied for each of the seven case study policies (Table 2). For example, for the South West Marine Reserve Network (SWMRN), the interviewees perceived that uptake of the relevant DST (Marxan) was *Low*. The facilitating factor "Tool is able to deal with missing information" was seen as *Important* by the interviewees, and as not being met by the DST. On the other hand, in the Southern and Eastern Scalefish and Shark Fishery (SESSF) interviewees perceived that the uptake of the DST (the Harvest Strategy Framework) was *High*. Based on the interviewee's responses, the facilitating factor "Existence of a relationship between agency staff and tool experts" was judged as *Important*, meaning that this factor facilitated uptake of the DST.

[insert Table 2 here]

The two policy challenges which had highest identified use of DSTs (SESSF and the Representative Areas Program (RAP)) recognised almost all of the factors as being important, the only exception for both being time taken to apply the tool for the RAP.

Overall, across all policy problems, the most important factor was "Tool capabilities align with policy objectives" (rated as important in six out of seven policies), with "Tool is able to deal with missing information" being rated next most highly (rated as important in five out of seven policies).

3.1 How well the tool capabilities align with the policy objectives

The need for the policy objectives and tool capabilities to align was considered an important factor in tool uptake in six out of the seven policy cases. For the policies where there was a perceived match between the decision tool and policy objectives (e.g., the SESSF and Representative Areas Program (RAP)), interviewees noted that the advantages of using the tool included the ability to set quantitative and transparent targets.

There were a few examples where the policy objectives did not match the decision tool. In the case of the SWMRN, there was a perceived mismatch between the decision tool, Marxan, and the policy objectives, which contributed to the low uptake of Marxan in the policy process. The Draft Management Plan for the network states that the reserves were,

> *"proclaimed for the purpose of protecting and maintaining marine biodiversity, while allowing for the sustainable use of natural resources in some areas"* (Director of National Parks 2013, pg 7).

An interviewee confirmed that this socio-economic objective of sustainable use was indeed a priority in the decision making process and there was a perception that it was not able to be adequately captured within Marxan. This was stated by the interviewee as one of the primary reasons for the limited use of the Marxan output. Interestingly, Marxan was in fact designed for exactly this objective, highlighting that a barrier can be due to perceptions rather than an actual limitation of the tool.

The National Reserve System (NRS) provided another example of a perceived mismatch between the policy objectives and decision tool capabilities (Marxan). The operational context of the policy was cited as the main reason for the mismatch by the interviewee. The acquisition of land is based on a voluntary scheme, where the landholder approaches the Government;

> *"one of the restrictions ... is that* [the Government can't] *actively pursue properties".*

However, in a Marxan analysis all land considered for inclusion in a reserve is assumed to be available. Thus, while Marxan was considered by the policy advisors, it was not deemed suitable to determine the actual decisions.

The interviewees for the Threatened Species Protection policies in New Zealand, the Australian state of New South Wales, and Australia (national government) also agreed that the match between the decision tool capabilities and policy objectives was at least somewhat important in facilitating use of the tool. For two of these policies, there was moderate uptake in the decision process of the tool, Project Prioritisation Protocol (PPP). This was considered useful for some aspects of threatened species management, such as setting priorities for species that are (locally) site managed and where the management actions (and subsequently costs) were better understood relative to species managed at a landscape scale. On the other hand, the Australian Government made no use of the PPP in its threatened species policy. Many recovery plans for species already exist and are set in national legislation. Although there is, in fact, insufficient funding to implement all of these recovery plans (meaning that some form of prioritisation is unavoidable), the explicit use of a prioritisation tool was seen as undesirable from the agency perspective because it conflicts with the official legal position that all species must be protected. In other words, the problem was not a weakness in the DST, but reservations about the public transparency and political implications from any prioritisation tool.

3.2 Ability of tool to deal with missing information

In five out of seven cases, interviewees considered it important that the decision tool was able to deal with missing or poor-quality information. In a number of cases, the relevant tools were perceived to be flexible in the case of insufficient data, and it was perceived that this improved their uptake. This was true for the SESSF, RAP, and New Zealand Threatened Species Protection policies. Some of reasons stated for this positive perception included that: assumptions or adjustments could easily be made where data were missing (Harvest Strategy Framework); the aspects of the tool that did not perform very well in the event of missing data were identifiable and related output could be treated with caution (Harvest Strategy Framework); or, gaps could be filled using expert judgement (Marxan's use in the RAP).

The ability of some tools to deal with missing data was not perceived so favourably. Interestingly, there were differences in this result between different (though similar) policies

with the same decision tool. While the interviewee for the RAP viewed Marxan as very capable in addressing data limitations, the interviewee for the SWMRN did not. In the SWMRN case, there were concerns that the available data was too old, not forward looking, and that there was a lack of socio-economic information. It was perceived that Marxan could not deal with these limitations well, which contributed to the limited reliance on the tool. Similarly, for the Project Prioritisation Protocol tool, the interviewee for New Zealand Threatened Species Protection viewed the tool's ability to deal with missing data positively, but the interviewee for the Australian Government policy equivalent did not. In the New Zealand case, the format of the data required was thought to assist the tool's application. In the Australian case, the format required did not match the way in which data were collected for the legislated species recovery plans, and there would be costs of employee time involved in reformatting. The latter case was reported to have contributed to the lack of uptake of the decision tool in the Australian Government policy process.

3.3 Relationships between agency staff and tool experts

There was not a clear consensus about the effect of relationships on tool uptake. In five out of seven policy situations it was ranked at least somewhat important. The degree to which relationships with agency staff and tool experts influenced tool uptake was considered important for those policies where a decision tool was used and not important where a decision tool was not used. One reason for the difference may have been an existing capability within the agency to implement the tool. For example, in the case of the SWMRN, there was existing capability within Department of the Environment to use Marxan. In comparison, the Harvest Strategy Framework was designed by CSIRO researchers specifically for Australian Fisheries Management Authority (AFMA) to use in the SESSF. One interviewee for this policy noted that the relationship between agency staff and the CSIRO tool expert was instrumental in its successful uptake by the agency.

It was noted by one interviewee that there are three to four layers of bureaucracy within the relevant agency, making it difficult for advice to reach the level at which decisions are actually made. This may suggest that having within-agency tool experts to act as "champions" would be beneficial for DST uptake. However, this suggestion did not resonate with many of our interviewees, apparently because such champions are only perceived to be influential if they are at a high-enough level in the bureaucracy. Similarly, they tended not to rate highly the role of external tool experts as "advocates". Other writers have argued that an

internal champion can facilitate DST uptake (e.g. Jacobs 2002; Pannell and Roberts 2009), but this study suggests that they may not be critical.

3.4 Presence of large numbers of stakeholder groups affected by the outcome

The results for "Presence of large numbers of stakeholder groups affected by the outcome" were polarised, being suggested as important in three policy cases, not important in three and not applicable in one (Table 2).

It can be difficult to engage multiple stakeholders in a timely and effective manner. The information obtained from the interviews suggests that, for two authorities (the Great Barrier Reef Marine Park Authority (GBRMPA) and AFMA), using the decision tool to demonstrate outcomes from different policy designs facilitated the stakeholder-engagement progress. Boundary setting and removing ambiguity were noted as particularly valuable capabilities. For example,

> *"[Harvest Strategy Framework] places boundaries around the conversations we have with stakeholders"*,

and

> *"…having the Marxan maps provided some definition for discussions, making them manageable."*

Interestingly, in the case of the SWMRN, the decision tool, Marxan, was not perceived to be important in the stakeholder-engagement process and therefore was not used. One reason given was that the policy maker perceived the DST output as one of many inputs into the decision making process, but the stakeholders tended to interpret the DST outputs as indicative of a final decision. This perception was only expressed by officers from the national Department of the Environment; it was not expressed by officers from the other organisations for which Marxan was potentially relevant, GBRMPA and AFMA.

3.5 Adequate time in the decision process for the tool to be used and time taken to apply the tool

Two aspects were considered in relation to how time might have affected the likelihood of the DST being used in the policy process: (1) the length of time permitted for development of

the policy; and (2) the time required to apply the tool itself. The importance of time as a factor in facilitating uptake varied across policies and tools.

Overall the time taken to apply the tool was not considered to be an important determinant of tool use; only in two out of the seven policy cases was it deemed at least somewhat important. The time needed for each tool's application varied, but was not related to the importance of the policy. For example, the Harvest Strategy Framework took a few months to implement for the SESSF, while those undertaking the Marxan analysis for the RAP were engaged in the policy process for over a year. The time taken to apply the tool was not deemed to be important in determining tool use in either case, suggesting that there was adequate time available for development of the policy.

The length of time permitted for the policy process affected tool uptake inconsistently, even though all of the policies studied were developed over reasonably long timeframes (relative to some policies). For the SESSF, RAP, and New Zealand Threatened Species Protection, there were lengthy processes in overhauling the policies. There was plenty of time available to create or select, apply and interpret outputs from an appropriate tool. In the case of the SESSF, the policy process also provided time to develop and adapt the decision tool. This is because fishery management is an ongoing adaptive process, rather than a one-off decision, so the decision tool itself can be adapted over time. Nevertheless, there are sometimes "windows of opportunity" to institute major changes, and this occurred with the SESSF harvest strategy in 2005. For the New Zealand Threatened Species Protection policy, the interviewee noted that having ample time was also important to permit staff consultation and adoption of the DST.

The SWMRN, also involved a lengthy policy process; however, this was not perceived to be an important factor in relation to tool uptake, perhaps because the tool was already not considered to be highly suitable to the task, for other reasons. On the other hand, the time needed to apply the tool was considered to be an important inhibiting factor in the use of Marxan to inform reserve design (reflecting high costs of staff time rather than a constraint on the available time). This is in contrast to the RAP, where application time for the same DST was not considered to be an important factor influencing uptake.

For the NRS, time was an important factor in contributing to the lack of use of the decision tool, Marxan. The interviewee noted that there was a tradeoff between having more complete

information, as would be provided by a Marxan analysis, and efficient use of time. In their opinion, sufficient information to make adequate decisions could be provided by a short set of questions that could be applied much more quickly than using a DST. In this policy context, application of the DST was considered to be a waste of resources.

3.6 Other factors

Beyond these factors from the literature, a number of additional factors emerged in the interviews as important in the uptake of decision tools. The first relates to 'equity'. In relation to the NRS, the interviewee noted the importance of 'equity', interpreted as a reasonably even distribution of funds across regions. This equity rule is often not officially stated in policy objectives, but is sometimes an implicit concern of governments. The authors are aware of cases in Australia where funding allocations of conservation programs have been explicitly adjusted to achieve this type of distributional 'equity'. Almost any prioritisation tool risks conflicting with this, which may contribute to tool non-use in some cases. However, it does not necessarily follow that 'equity' should be explicitly included in the DSTs. It may be sufficient for decision makers to make subjective *post hoc* adjustments. The appropriate handling of equity in decision tools is an issue that may justify additional investigation.

The second factor is that DSTs were more likely to be used and viewed favourably by the relatively autonomous agencies (i.e. the Australian Fisheries Management Authority and Great Barrier Reef Marine Park Authority) compared with the national agency. Interviewees from these agencies also commented that they have used other DSTs for policy making.

Next, where a policy had multiple (potentially conflicting) objectives, it was sometimes unclear what "weight" was placed on each objective. This reduced the ability of the DST to assist the policy needs. For example, in the South West Marine Reserve Network (SWMRN) the two policy objectives were: protecting and maintaining marine biodiversity; and sustainable use of natural resources in some areas. It appears that the policy makers placed a higher weight on the sustainable use of natural resources than on conserving marine biodiversity. The policy makers viewed Marxan as limited in its ability to trade-off socio-economic and biodiversity outcomes, although Possingham et al. (2009) explained that these trade-offs are able to be incorporated in the Marxan.

Employee time costs and data costs can be significant with some DSTs, and this emerged from the interviews as an additional key facilitating factor for DST use. Interviewees

359 expressed the importance of communicating the costs and benefits of using a DST to policy
360 makers, so that policy advisors can make an informed decision on whether using the DST is
361 worthwhile. Rogers et al. (2015) found that policy makers sometimes think there is too much
362 effort for too little gain when considering use of non-market valuation to inform policy, and it
363 appears that the same applies to DSTs. One interviewee summed up the DST use decision for
364 the NRS:

365 *"…there is no advantage to asking 120 questions when you just need these five."*

366 The final additional factor relates to communication: how well the purpose, usage, results and
367 value of a DST are communicated to policy makers and stakeholders, and how well the
368 policy context is communicated to the DST developers. For example, one interviewee said,
369 "*The Marxan tool, when well-presented, can empower us to engage more effectively with*
370 *stakeholders".* Another interviewee emphasised the importance of *"a translator to*
371 *communicate the tool to managers and the policy context to researchers".*

372

373 **4. Discussion**

374 The purpose of this study was to seek insights on policy makers' views on the factors that
375 lead to the use or non-use of DSTs during the development of conservation-related policies
376 and programs. Decision support tools, like the Harvest Strategy Framework and Marxan, can
377 be very useful to policy makers for clarifying priorities, and for exploring and presenting
378 trade-offs. They can help to define boundaries to the choice set, and increase transparency.
379 They can also facilitate engagement with stakeholders by explicitly revealing who wins and
380 who loses, and by how much, under different policy settings. For example, in the SESSF
381 (Fulton et al. 2014), the decisions makers are not the only managers: the fishing industry and
382 environmental NGOs also hold interests in fishery management. However, the three groups
383 can have different perspectives and priorities. An appropriate DST can facilitate the
384 engagement between them and result in more effective policy.

385 Despite these benefits, uptake of the DSTs was mixed across the different policy case studies,
386 sometimes even for the same DST across a range of similar contexts. A good example of
387 DST use in decision making is provided in the Southern and Eastern Scale-fish and Shark
388 Fishery (SESSF) case study. The policy had to apply to all important commercial species, but

the information base varied enormously across species. The researchers, therefore, developed a "tiered" harvest strategy framework that could be applied across the spectrum from data rich to data poor stocks. Supplementary tools, including simulation-based management strategy evaluation (Smith et al. 1999), were used to ensure that the strategy at each tier met the intent of the policy (to avoid overfishing). On the other hand, the national government's Department of the Environment did not make extensive use of either of the DSTs that were relevant to their case studies: Project Prioritisation Protocol and Marxan.

We identified various factors from the literature that may explain use or non-use of DSTs in these types of policies, and our results provide insights into how important these factors have been, at least in the seven case studies we have investigated. The managers we interviewed indicated that the alignment of a DST with policy objectives and its ability to be useful even in the presence of missing data were two of the most important factors influencing use of DSTs when developing these policies. On the other hand, two other factors from the literature were perceived by the managers as being less important: the presence of a champion of the DST within the management agency, and the time required to apply the tool.

The interviews also revealed a range of additional factors that we had not identified from the literature, including the existence of multiple (potentially unstated) policy objectives, the autonomy of the agency, the employee time costs of applying the DST, and the quality of communication.

There were a number of reasons suggested as to why the relatively autonomous agencies (AFMA and GBRMPA) were more likely to use DSTs. Both agencies have a long history of engagement with and use of research, which seems to have grown from a preference to hire staff with research training and/or a skill set in marine science, fisheries management or ecology. Staff and researcher networks were well established, given that staff generally stayed in the same policy area for a long time. By contrast, in the public service of the Australian Government, there is a culture that encourages rapid movement between jobs and often even between agencies, and plays down the importance of content expertise.

Another possible explanation for the difference arises from the autonomy in how AFMA and GBRMPA operate and make decisions. They do operate within broad legislative and policy frameworks, but they have operational flexibility about how goals are achieved, perhaps making it easier to adopt novel processes, relative to the national environment agency. They

are probably less prone to intervention by a government minister concerned with the politics of an issue, which is likely to make it easier for transparent and systematic decision processes to operate. They also have a greater emphasis on day-to-day engagement with stakeholders, such that the potential benefits of a DST in enhancing engagement may be more apparent.

Another interesting result was the diversity of views on Marxan amongst agencies responsible for essentially the same conservation management problem. To some extent this may reflect differences in the policy contexts or the clarity of communication, in terms of researchers effectively conveying the tool's capabilities and suitability for supporting policy development. However, it also may be due to attitudinal differences amongst the groups of people actually involved in the decision processes. In our experience there is wide variation amongst agency staff in the attitudes towards models, decision tools, and transparent, systematic decision processes generally. This may be as important in driving the recorded differences in perceived suitability as anything else. Negative attitudes to DSTs may be modified to some degree by training, persuasion or the development of trusted relationships, but they also may be deeply ingrained and difficult or impossible to change, even when they seem to be based on misconceptions.

This study offers a number of insights that may help to improve the use of DSTs in conservation policy. One key finding is that the likelihood of a DST being used well to support policy development depends in part on the nature of the body or agency which is being supported. We found that effective tool use was relatively more likely in agencies that were independent from central government to some extent, staffed by people with strong subject expertise (e.g. scientists) and more closely connected to stakeholders in the community. This suggests that, in prioritising their efforts, DST developers might choose to give less emphasis to large central government agencies that need to be most attentive to the concerns of political leaders, have rapid staff movements and are relatively distant from the community.

In a similar vein, we identified the importance of the individual attitudes and motivations of policy makers. Different individuals were observed to be more or less open to the potential benefits from a structured systematic approach to decision making, and this too may be relevant to DST developers when prioritising their efforts or developing their engagement strategies.

While it was not essential for there to be a champion or advocate to promote the use of a DST in these case studies, our results reinforce the recognised importance of clear communication between tool developers and agency staff. We were able to identify specific issues over which good communication by DST experts was particularly important: capabilities and limitations of the DST; how to deal with missing information when using the tool; how to use the tool in a way that supports, rather than conflicts with, policy objectives (perhaps including equity); and how the tool can be used to support constructive stakeholder engagement, including how to avoid creating the impression that model results determine decisions and over-ride other considerations. One the policy-maker side, there is a need to communicate clearly about a policy's objectives, including clarity about the relative importance of conflicting objectives.

In the longer term, uptake can be enhanced if the DST developers are able to develop a strong understanding of the policy context, its needs and constraints, and thereby adjust tools to better meet the needs of policy makers.

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Table 1 Description of each policy used for analysis.

Policy	Policy objective	Responsible agency	Location	Policy history and timeframe	Decision context	Matched suitable decision tool	Relevant literature
Threatened Species Protection: Commonwealth EPBC Act	The Act protects Australia's native species and ecological communities by providing for development of conservation advice and recovery plans for listed species and ecological communities.	Department of the Environment, Australian Government	Australian mainland and marine waters	EPBC Act 1999 – legislation commenced in 2000. Protection of threatened species as a legal requirement 2000-present.	Ongoing management	Project Prioritisation Protocol	Joseph et al. (2009)
Threatened Species Protection: New Zealand	While a threat classification system exists, there is no policy or legislation specifically for the protection of threatened species in New Zealand. Some listed species are protected if they satisfy the conditions of other conservation-related Acts.	Department of Conservation, New Zealand	New Zealand	Related Acts: Wildlife Act 1953; Marine Mammals Protection Act 1978; Conservation Act 1987; Resource Management Act 1991. Recent recognition that a dedicated policy for threatened species would be beneficial (e.g. Wallace & Fluker 2016).	Ongoing management	Project Prioritisation Protocol	Joseph et al. (2009)

Policy	Policy objective	Responsible agency	Location	Policy history and timeframe	Decision context	Matched suitable decision tool	Relevant literature
Threatened Species Protection: New South Wales	To align efforts under a single banner, so investment in threatened species conservation can be accounted for; assign threatened species to different management streams so the individual requirements of each species can be met; invite the NSW community and businesses to participate, because projects to save threatened species are collaborative efforts	Environment and Heritage, New South Wales	New South Wales, Australia	Threatened Species Conservation Act 1995 (NSW). EPBC Act 1999. Protection of threatened species as a legal requirement 1995 (State listed species)-; 1999 (Commonwealth listed species)-present.	Ongoing management	Project Prioritisation Protocol	Joseph et al. (2009); Szabo et al. (2009); Office of Environment and Heritage (2013)
Southern and Eastern Scalefish and Shark Fishery (SESSF)	To sustainably manage stocks for this complex multispecies fishery	Australian Fisheries Management Authority (AFMA)	The waters of sub-tropical south-east Queensland south to Tasmania and then westward to south-west Western Australia	Fisheries sustainability issues noted in early 2000s. Conditions placed on fishery in 2003 to adhere to EPBC Act. Policy development 2005.	Ongoing management	Harvest Strategy Framework	Smith and Smith (2005); Smith et al. (2008); Smith et al. (2014)
Representative Areas Program (RAP)	To improve biodiversity protection, primarily by increasing the extent of no-take areas in the park. An additional aim of the program was to maximise	Great Barrier Reef Marine Park Authority (GBRMPA)	Great Barrier Reef Marine Park (GBRMP), Queensland	Recognition of problem in 1990's. Policy development 1999-2004.	Discrete planning	Marxan	Ball et al. (2009); Fernandes et al. (2005)

Policy	Policy objective	Responsible agency	Location	Policy history and timeframe	Decision context	Matched suitable decision tool	Relevant literature
	benefits / minimise negative impacts of rezoning in the GBRMP						
South West Marine Reserve Network (SWMRN)	To manage the reserves (within the network) for the primary purpose of conserving the biodiversity found in them, while also allowing for the sustainable use of natural resources in some areas	Department of the Environment, Australian Government	The waters of Kangaroo Island (South Australia) to offshore from Shark Bay (Western Australia)	Recognition of problem in 1990's. Commitment to designing network in 1998. Policy development 2007-2012. Policy review 2013-2015.	Discrete planning	Marxan	Department of the Environment (2014); Possingham et al. (2009); Ball et al. (2009)
National Reserve System (NRS)	To protect 17 per cent of Australia's bio-regions in the National Reserve System by 2020	Department of the Environment, Australian Government	Mainland Australia	Ratification of Convention on Biological Diversity (Rio Earth Summit) 1992. Policy implemented under a variety of program names from 1992-present.	Ongoing management	Marxan	DoTE (2014c); Ball et al. (2009); Watson et al. (2010)

Table 2 The importance (not important, somewhat important or important) of factors that facilitate the use of decision tools in policy development.

Policy	Perceived level of tool use	Presence of a champion for the tool within the agency	Presence of an advocate for the tool outside of the agency	Existence of a relationship between agency staff and tool experts	Presence of large numbers of stakeholder groups affected by the outcome	Tool is able to deal with missing information	Tool can be applied quickly	Policy process allows adequate time for tool use	Tool capabilities align with policy objectives
Threatened Species Protection: Australian national	None	Not important	n/a	Somewhat important	Important	Somewhat important	Not important	n/a	Somewhat important
Threatened Species Protection: New Zealand	Moderate	Important	n/a[2]	Somewhat important	Not important	Important	Not important	Important	Important
Threatened Species Protection: New South Wales	Moderate	Somewhat important	Somewhat important	Somewhat important	Not important	Important	Not important	Not important	Important
Southern and Eastern Scalefish and Shark Fishery (SESSF)	High	n/a[1]	Important	Important	Important	Important	n/a	Important	Important
Representative Areas Program (RAP)	High	Important	Important	Important	Important	Important	Not important	Important	Important
South West Marine Reserve Network (SWMRN)	Low	Not important	Somewhat important	Not important	Not important	Important	Important	Not important	Important
National Reserve System (NRS)	None	n/a	n/a	n/a	n/a	n/a	Somewhat important	Somewhat important	Important

n/a: questions were not asked when they were deemed not relevant based on how the discussion was proceeding.

[1]There was an established relationship and trust between AFMA and the researchers commissioned to create the Harvest Strategy Framework, such that the Harvest Strategy Framework was used instantly and the step of internal championing was not necessary in this case. [2]This question wasn't asked because it was evident that the uptake of the tool was strongly driven internally.

Supplementary information for "Factors influencing the use of decision support tools in the development and design of conservation policy"

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Southern and Eastern Scalefish and Shark Fishery (SESSF)

The SESSF extends from the waters of sub-tropical south-east Queensland south to Tasmania and then westward to south-west Western Australia In the early 2000s a high proportion of fish stocks in the SESSF were overfished, making it difficult for the fishery to meet sustainability criteria under the Commonwealth Environment Protection and Biodiversity Conservation Act of 1999. As a result, a number of conditions were placed on the SESSF in 2003, including one requiring that a formal harvest strategy be introduced for key species. In 2005, researchers were engaged to develop a suitable Harvest Strategy Framework that could be applied to all 32 quota-managed stocks in the fishery. The harvest strategy was required to provide a formal set of rules for monitoring, assessing, and managing the fishery, including explicit decision rules for setting annual quotas. The process from initial development of the Harvest Strategy Framework to endorsement occurred within 3 months (Smith et al. 2008), although previous research on harvest strategies for several individual stocks had laid the groundwork.

Representative Areas Program (RAP)

In the mid-1990s concerns were raised that the system of zoning at the time were inadequate to protect the range of biodiversity that existed in the Great Barrier Reef Marine Park. Between 1999 and 2004, the Great Barrier Reef Marine Authority undertook a systematic planning and consultative program. *The Great Barrier Reef Marine Park Zoning Plan 2003, which* was developed as a result of the RAP and has been in operation since 1 July 2004 (GBRMPA 2011).

Fernandes et al. (2005) outline the main steps in the process applied in the GBRMP.

South West Marine Reserve Network (SWMRN)

The SWMRN extends from the waters of Kangaroo Island (South Australia) to offshore from Shark Bay (Western Australia). In 1998 the Commonwealth, States and Northern Territory governments committed themselves to establishing the National Representative System of Marine Protected Areas by 2012. Bioregional Profiles were released for the South-west Marine Region in October 2007. A draft proposal was released in May 2011 for public feedback. The reserves came into effect on 17 November 2012. The management plan review is currently in progress.

Possingham et al. (2009) undertook a Marxan analysis to identify a set of marine sanctuaries that would cover the smallest area while satisfying the condition of protecting important conservation features and having the smallest displacement of existing uses.

National Reserve System (NRS)

The NRS has its origins in the Rio Earth Summit of 1992. Between 1992 and 1996, $11.5 million was spent on the National Reserve System Cooperative Program. By 1996, the Program consisted of more than 5,600 properties covering almost 60 million hectares. Between 1996 and 2007, an additional 30 million hectares were added to the reserve system. In March 2008, the new Australian Government announced that the NRS would be one of its

six priorities under a new environmental initiative called Caring for our Country. The Government committed increased funding of $180 million over five years (DotE, 2014)

Watson et al. (2010) examined the distributions of 1320 nationally listed species on Australia's EPBC Act and assessed how well the nation's 9000 plus reserves (covering 11.6% of Australia) protects these species. They found over 80% of the species analysed were inadequately protected. Using Marxan, they devised a reserve system that protected target numbers of threatened species for the least cost.

Threatened Species Protection – Commonwealth and State Government

The Environment Protection and Biodiversity Conservation Act 1999 focuses Australian Government interests on the protection of matters of national environmental significance. Each state and territory has responsibility for matters of state and local significance, meaning there is often some cross over in species listings. The Act is a means for identification and listing of species and ecological communities as threatened; development of conservation advice and recovery plans for listed species and ecological communities; development of a register of critical habitat; recognition of key threatening processes; and where appropriate, reducing the impacts of these processes through threat abatement plans.

Threatened Species Protection – New Zealand

The Statement of Intent produced for the 2011-2014 period sets out the aims for improving the state of New Zealand's natural heritage and contributes to the New Zealand Biodiversity Strategy. A key objective is to provide better conservation returns from the management of species and ecosystems within existing funding levels.

Joseph et al. (2009) used a subset of 32 species listed on New Zealand's list of threatened species to illustrate the Project Prioritisation Protocol (PPP). They found the use of PPP can substantially improve conservation outcomes for threatened species by increasing efficiency and ensuring transparency of management decisions.

Threatened Species Protection – New South Wales (NSW) Saving our Species

Saving our Species covers all species, populations and communities listed as threatened in the NSW Threatened Species Conservation Act 1995. It also covers many species listed in the Commonwealth Environmental Protection and Biodiversity Conservation Act 1999 that occur in NSW. The program objective is to maximise the number of threatened species that are secure in the wild in NSW for 100 years.

Szabo et al. (2009) used the Project Prioritisation Protocol for an example case study on a sample of 20 threatened species in the NSW. They found assigning funding to recovery of threatened species based on PPP equation allows the most recovery of species (10 of the 20 threatened species in the example).